The Angle Orthodontist

April • 1959

Published Quarterly by

The Edward H. Angle Society of Orthodontia

Published Quarterly by the
EDWARD H. ANGLE SOCIETY OF ORTHODONTIA
Zuelke Building, Appleton, Wisconsin
Subscription Rates: $6.00 per year, Canada $6.25,
other foreign countries $6.50.

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Application to mail at 2nd class postage rates is pending at Appleton, Wis.

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Volume 29, Number 2

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The Variations In Skeletal And Denture Patterns In Excellent Adult Facial Types*

SAMUEL GOLDSMAN, D.D.S., M.Sc.D.

Niagara Falls, N.Y.

The purpose of this research project was to investigate the dentoskeletal patterns of Caucasian adults having excellent faces. This objective was further to be defined by studies of central tendency, dispersion, and correlation.

Aspects of dentoskeletal pattern to be considered included mandibular prominence or retrusion, profile convexity, tooth axial inclination, vertical height proportions, and structural dysplasia in the anteropostero plane.

In addition, the variations were contrasted according to sex and by comparisons with previous studies based on samples characterized by excellence of occlusion.

FACIAL ESTHETICS

The problem of facial harmony and the intrarelations of the dentofacial complex, while consistently occupying the attention of dentists and orthodontists in particular from the time of Hunter and even before, has always been an elusive concept because of the infinite range of the variations inherent in the morphogenic pattern and the nebulous and indefinite nature of the subject itself. Yet, the importance of esthetics as a basic aim of orthodontic therapy needs little elaboration. In fact, Hunter[1] in the eighteenth century had suggested that the prime objective of this treatment was to beautify the appearance of the mouth.

The question must be asked: What constitutes an excellent face? Is there any demonstrable, quantitative criterion from which an excellent face can be defined in terms applicable to the needs of the orthodontic clinician? Stoner[2] has suggested that each man's concept of facial beauty is a function of his own innermost sensibility and understanding. Yet, he points out, ". . . there most certainly is considerable agreement among many of us that certain faces fall well within the definition of . . . . harmony of form." Orthodontists generally share Angle's conviction that "The study of orthodontia is indissolubly connected with that of art as related to the human face,"[3] but does not the great universal genius of the Renaissance, Da Vinci, tell us: "The most admirable faces are those whose expression best reveals the passions of the soul."[4] It is clear that the question of facial beauty inspires sympathetic consideration as much by the scientific research worker as it does by the subjective artist, and that facial beauty is a function of the facial feature in balance and harmony.

The first American to apply the term "dentofacial orthopedics" was Calvin Case in 1896.[5] There are countless references in Case's writings of his preoccupation with esthetics and his interest in the fine arts and their influence on orthodontics.

Edward H. Angle admonished the orthodontic profession to have "fixed in our minds the outline of the perfect face . . . ." His intimate concern with the question of facial esthetics is well known to all students of the history of

Thesis submitted as partial fulfillment of the requirements for the degree, Master of Science, University of Indiana.

orthodontics. Angle considered that all the essentials of beauty and perfection were to be found in the statue of Apollo Belvedere.

Tweed and his followers have been the conspicuous leaders of the revival and reemphasis in recent years of improvement in facial esthetics as a practical and basic goal of orthodontic therapy. Tweed has placed esthetics first in his list of treatment objectives; to achieve this objective he has advocated in many instances the extraction of dental units. Thus, on a basis of clinical experience, he disputes Angle's dictum concerning the necessity for maintaining a full complement of teeth in order to gain the ultimate excellence of occlusion and, according to Angle, the ultimate in facial balance and harmony. Tweed has placed particular emphasis on facial esthetics because he is convinced that good occlusion is possible only where there is reasonable balance between the various component parts of the dentofacial complex, and ". . . only when normal occlusion accompanies a normal face pattern is the ultimate in balance and harmony of the facial lines possible."[6]

Beauty of facial lines does not depend alone on beautifully aligned and ideally occluded teeth but upon the sum total of intra-relationships between all the structures that enter into the formation of the dentofacial complex. Therefore, the basic etiology of malocclusions may lie in the faulty development or malrelation of these parts. Logically, Angle's major premise of ideal occlusion per se as the prime requisite for the balance and harmony of facial parts may be faulty, since the basis for ideal occlusion is the ideally coordinated development of *all* the structures of the face and cranium. The one rule in the fine arts for the application of rigid standards to the ideal face is that there are no rules: every face differs from every other one to a greater or lesser degree! Yet, there are fundamental principles in art, the expression of which signifies beauty — when lines are in *balance* and *harmony,* they possess two of the fundamental qualities which govern the degree of perfection of the product of the artist. The specialty of orthodontics revolves around a ceaseless pursuit of this.

Cephalometric Methods

The most significant advancement in orthodontics in recent years is the widespread employment of cephalometrics as an analytical tool and diagnostic aid. With the development of techniques for routine appraisal of patients, the cephalometer has been increasingly accepted as the most efficient means for studying therapeutic and prognostic possibilities and limitations. It is a convenient procedure for analyzing abnormalities, localizing and recording the degree and direction of discrepancy; it can be applied to functional and to soft tissue analysis; it makes possible the more accurate classification of facial types; it is used for the study of completed cases; it is a time-linked technique which enables the investigation of problems of growth and development through the dynamic analysis of serial studies. Downs has observed: "Cephalometrics is to the orthodontist what the dissection room is to the anthropologist and anatomist".[7] The introduction of the cephalometer in the United States as an analytical tool in orthodontics is credited to Broadbent (1931).[8]

Tweed emphasized the significance of the Frankfort mandibular plane angle in diagnosis.[9] He suggested that the steeper the plane (the higher the angulation), the poorer the prognosis insofar as improvement of facial esthetics is concerned. E. L. Johnson also affirmed this in a later and more comprehensive study.[10]

Margolis, who had been among the first to report on the axial inclination of the lower incisors[11], introduced the maxillofacial triangle in 1947[12]. He felt that the character of this triangle was sufficiently narrow so as to establish a basic facial pattern. Tweed introduced a modification of this triangle in 1954[13], using more conventional registration points and planes. In a reanalysis of his own treated cases, he came to the conclusion that the best esthetic results were obtained in those cases having a Frankfort mandibular plane angle of 25°, an axial inclination of mandibular central incisor tooth to mandibular plane of 90°, and, therefore, an angulation of 65° of mandibular central incisor tooth to Frankfort plane. This latter measurement is considered by Tweed to be of paramount importance.

The precise quantitative definition of mandibular central incisor tooth positioning devised by Tweed was the subject of an article by Wylie[14]. Wylie, reanalyzing Tweed's sample, came to the conclusion that Tweed oversimplified his treatment concept and the explanation of his results, and that the uprighting of the mandibular central incisor teeth to a 65° angulation with Frankfort plane was only one element, and not necessarily the most important, in his most successful cases. Wylie suggested that the remarkable facial changes were rather a function of Tweed's extraordinary ability to elicit mandibular growth in the majority of these cases.

Wylie[15], in a study of mandibular, nasal, and dental heights, showed that these were among the most stable of dentofacial dimensions. Accepting as valid the theses of Brodie[16] and of Broadbent[17] regarding the constancy of the proportionality of the facial parts during growth, he developed as a consequence an assessment of anteroposterо dysplasia[18]. Later, Wylie and Elsasser elaborated on this in a study on the craniofacial morphology of mandibular retrusion[19]. Wylie and E. L. Johnson studied mandibular and vertical dimensions and relationships in an evaluation of facial dysplasia in the vertical plane[20].

Downs, using a sample of young adults having excellent occlusion, studied the variations in skeletal and denture relationships inherent in these facial patterns and pointed out their importance in prognosis and in treatment[21]. Riedel studied, on a somewhat similar sample, the anatomical relationships using the plane from nasion to sella turcica as the principal plane of reference,[22] instead of Frankfort horizontal (as in Downs' method). Riedel, in a later study, applied the analysis of Downs to a sample of better-than-average faces.[23]

Jensen and Palling, in a recent survey of the gonial angle, showed that, while this angle cannot by itself be responsible for marked facial disharmony, it may well reflect the coordination and proportion between the various parts that constitute the unity of the face.[24]

The outstanding advantage of applying cephalometric roentgenographic procedures to craniofacial measurements is that they facilitate measurements on living subjects which would otherwise be impossible. Indeed, cephalometrics has progressed to the point where it is no longer the tool of the research worker, but is a necessary adjunct to a complete and well planned case analysis from which a diagnosis may be derived. It is not a panacea that will supplant all other methods of analysis and answer all of the orthodontist's diagnostic problems and can never take the place of conscientious clinical observation. But so long as the science of orthodontics remains a problem of relations within the dentofacial com-

plex in which, "all we ever find are variations, endless variations . . . ."[25] then cephalometrics will be an invaluable tool supplementing all other procedures of analysis.

Method and Materials

A total of one hundred and sixty cases, chosen by perspection as representing better-than-average Caucasian adult faces of no particular ethnic group, were photographed full view and profile view oriented with Frankfort plane, using the photographic and cephalometric facilities of the Indiana University School of Dentistry.

This rather arbitrary sample was then subjected to a critical evaluation by an impartial jury of artists from the Herron Art Institute of Indianapolis, Indiana and the Buffalo Art Institute, Buffalo, New York. The panel of artists selected those faces, fifty in number, which could be considered excellent.

The artists displayed a startling unanimity in their selection of the cases to be analyzed and, as might be expected, their conception of ideal facial harmony was rather more liberal than that of orthodontists. It was felt that a broader sampling would occur if people in the fine arts served as the jury rather than orthodontists, who might well have preconceived and somewhat prejudicial ideas of what constitutes ideal facial balance and esthetics.

When the fifty cases were submitted to the staff and graduate students of the Department of Orthodontia, Indiana University for their critical appraisal, there were some definite areas of disagreement: the artists' sample of excellent faces included some concave and some convex types — in other words, a representative sampling of diverse facial types. The orthodontists, on the other hand, tended to prefer those faces which fell within the definition of "flat" or vertical or concave profiles. The panel of artists, in their critical appraisal of the photographs, studied the face as a whole, but placed some emphasis on the profile and, in rather the same manner as the orthodontists, stressed that their attention was particularly attracted to the lower face — the area from mouth to chin — as it fitted into the entire face.

The fifty cases selected were procured from the files of current patients of the Indiana University School of Dentistry, from the ranks of students, and other personnel of the Indiana University Medical Center. The cases were, on the whole, representative of various economic and social levels. There were nineteen males and thirty-one females of ages ranging from fifteen to thirty-six and averaging twenty-three and one half years.

Every one of the fifty cases displayed Class I molar relationships. Except for Case No. 46, the sample consists of untreated cases. The photographs, orientated with the Frankfort plane, of some of the cases used in this investigation are shown in Figures 1, 2 and 3.

Method

Accurate cephalometric roentgenograms, anteropostero and lateral headplates, were taken in occlusion with the cephalometer of the Department of Orthodontia. These records were made according to the Broadbent-Bolton technique for the standardization of profile x-rays, using a fixed position of the x-ray tube and a cephalostat for positioning of the head with a sixty inch target distance.

Since all roentgenograms are enlargements and are subject to x-ray distortion, the question of error in cephalometric registrations and their consequent effect on measurements made therefrom had to be considered.

Fig. 1

Fig. 2

Fig. 3

This problem was the subject of a comprehensive investigation by Adams[26]. Adams reported that this error is within acceptable limits of experimental accuracy, even though the subjects differ in absolute size.

Tracings were constructed from the profile roentgenograms and the material analyzed according to methods suggested by Downs, Tweed, Wylie, E. L. Johnson and Riedel, as well as some modifications of their techniques which will be described as each analytical method is considered. When the means and acceptable ranges of variations therefrom were established by determining the standard deviations, polygons (after Adams and Vorhies[27])

TABLE I

The Indiana Sample: Summary of Readings according to Downs' Method.

		Combined Sample	*Males*	*Females*
Facial Angle	M	86.0	85.8	86.2
	SD.	±2.80	±1.94	±3.09
	R	80.0 to 92.0	80.0 to 89.2	80.0 to 92.0
Angle of Convexity	M	—1.0	—2.2	—0.3
	SD.	±5.50	±4.47	±5.88
	R	—11.6 to +14.0	—11.6 to +5.0	—10.0 to +14.0
A-B Plane Angle	M	—4.1	—3.2	—4.7
	SD.	±3.10	±2.99	±3.12
	R	—10.5 to +4.5	—8.3 to +4.5	—10.5 to +0.5
Mandibular Plane Angle	M	25.4	24.9	25.7
	SD	±3.83	±3.62	±3.90
	R	16.5 to 36.0	16.5 to 32.8	17.0 to 36.0
Y-axis Angle	M	61.8	62.54	61.38
	SD.	±3.74	±2.94	±3.34
	R	56.5 to 70.0	57.5 to 68.0	56.5 to 70.0
Cant of Occlusal Plane	M	8.6	7.6	9.2
	SD	±4.30	±4.55	±4.09
	R	2.4 to 19.5	2.4 to 17.0	3.2 to 19.5
$\overline{1}$ to Occlusal Plane	M	15.6	14.92	16.04
	SD.	±5.69	±5.39	±5.78
	R	5.0 to 30.0	5.0 to 27.0	6.0 to 30.0
$\overline{1}$ to Mandibular Plane	M	—0.4	+0.14	—0.65
	SD.	±5.83	±6.09	±5.61
	R	—15.0 to +12.4	—11.0 to +11.0	—15.0 to +12.4
$\underline{1}$ to $\overline{1}$	M	136.1	137.3	135.3
	SD	±8.34	±7.91	±8.79
	R	110.5 to 151.0	120.5 to 151.0	110.5 to 148.0
$\underline{1}$ to A - P Plane (in mm.)	M	3.6	3.7	3.6
	SD.	±1.95	±1.98	±1.91
	R	—0.8 to +8.6	0.0 to +8.0	—0.8 to +8.6

M = Mean
SD = Standard Deviation
R = Range

were constructed summarizing some of the measurements. Correlations were established and tests for reliability and significance were also conducted.

Observations and Findings

1. The measurements made according to Downs' technique of analysis are summarized in Table I.

2. The measurements observed according to the analytical method of Riedel, using S-N (Sella-Nasion) as plane of reference, are summarized in Table II.

3. The measurements derived from the evaluation of vertical dysplasia, according to a technique suggested by Wylie, are found in Table III.

4. Data derived from an assessment of anteropostero dysplasia, according to a method suggested by Wylie, are summarized in Table IV.

TABLE II

The Indiana Sample: Summary of measurements related to S-N plane, according to the analytical method of Riedel.

	Combined Sample
SN - Point A	
M	81.22°
SD	±3.11
R	74.6 to 87.0
SN - Point B	
M	79.79°
SD	±3.21
R	73.0 to 86.0
Difference	
M	1.42°
SD	±2.17
R	—4.0 to +7.1
SN - Gnathion	
M	80.5°
SD	±3.79
R	71.1 to 87.0
SN - Mandibular Plane	
M	29.3°
SD	±5.50
R	15.5° to 44.0°
SN - $\underline{1}$	
M	105.0°
SD	±6.98
R	91.2° to 122.5°

TABLE III

The Indiana Sample: Summary of measurements derived from the evaluation of vertical dysplasia.

	Combined Sample
Ramus Height (mm.)	
M	59.6
SD	±5.88
R	48.2 to 73.1
Gonial Angle	
M	123.8°
SD	±6.25
R	110.5° to 138.6°
Lower Border of Mandible (mm.)	
M	79.8
SD	±4.76
R	70.0 to 90.9
Total Face Height (N-Gn)	
M	121.63
SD	±7.41
R	106.6 to 137.1
Upper Face Height (N-ANS)	
M	55.1
SD	±3.32
R	49.3 to 63.5
Lower Face Height (ANS-Gn)	
M	66.6
SD	±5.88
R	54.5 to 78.5
$\frac{\text{UFH}}{\text{TFH}} \times 100$	
M	45.5
SD	±2.34
R	40.0 to 50.8
$\frac{\text{LFH}}{\text{TFH}} \times 100$	
M	54.5
SD	±2.26
R	49.2 to 60.0

UFH = Upper Face Height
LFH = Lower Face Height
TFH = Total Face Height

TABLE IV

The Indiana Sample: Summary of measurements derived from an assessment of antero-postero dysplasia, according to Wylie's method.

	Combined Sample
LENGTH MANDIBLE	
M	116.5
SD	±5.93
R	102.0 to 134.1
PORION-SELLA	
M	22.8
SD	±4.10
R	12.0 to 29.5
SELLA-PTM	
M	16.8
SD	±2.21
R	12.0 to 21.5
PTM - ⌊6	
M	20.3
SD	±4.40
R	11.0 to 30.0
ANS-PTM	
M	57.4
SD	±3.69
R	51.0 to 66.0
UNIT DYSPLASIA SCORE	
M	−0.85
SD	±5.20
R	−12.0 to +13.0

PTM = Pterygomaxillary Fissure
ANS = Anterior Nasal Spine
⌊6 = Maxillary 1st Permanent Molar Tooth

TABLE V

The Indiana Sample: Summary of readings showing the axial inclinations of maxillary and mandibular central incisor teeth related to the Frankfort horizontal.

MAXILLARY CENTRAL INCISOR TOOTH RELATED TO THE FRANKFORT PLANE	*Combined Sample*
M	109.2°
SD	±6.01
R	96.0° to 122.0°
MANDIBULAR CENTRAL INCISOR TOOTH RELATED TO THE FRANKFORT PLANE	
M	65.4°
SD	±5.79
R	52.4° to 75.0°

M = Mean
SD = Standard Deviation
R = Range

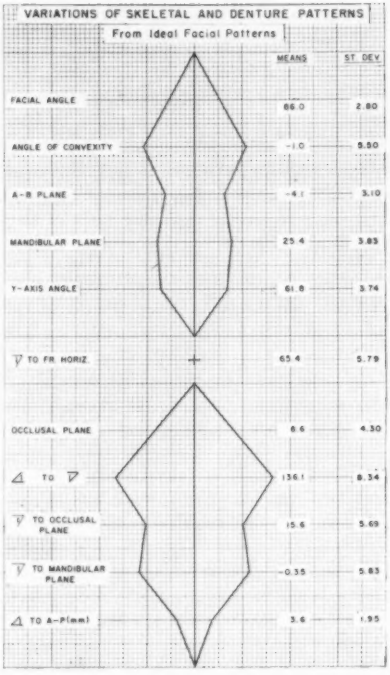


Fig. 4 The Facial Skeleton Polygon for the combined sample of 50 cases. The polygon is constructed to demonstrate two standard deviations plus and minus from the means, which are arrayed along the center line. Each scale division represents one angular degree or one millimeter as the case may be.

5. Axial inclinations of the incisor teeth related to the Frankfort horizontal are noted in Table V.

Fig. 4 shows a polygon for the combined sample of fifty cases, constructed from the ten measurements used in the original Downs' analysis and also in this report. In addition, the measurement relating the mandibular central incisor teeth to Frankfort horizontal has been included because of the interest stimulated by the work of Tweed.

A range of two standard deviations on either side of the mean is used here in lieu of the range of extremes plotted

in the Indiana Polygon by Adams and Vorhies[27].

The polygon derived from the measurements observed in this study will be referred to, from now on, as the "Facial Skeleton Polygon". Generally speaking, in the polygonic method of illustrating qualitative and quantitative mathematical observations for a static cephalometric analysis, the readings falling to the left of the center line, or mean, indicate a Class II tendency; those falling to the right a Class III trend.

Comparisons of the Indiana sample with the Analyses of Downs and Riedel

The Facial Angle The mean of the Indiana sample for this angulation is 86.0°, which is smaller than either Downs' reading (87.8°) or that of Riedel (88.6°). The differences of 1.8° between the readings for the Indiana sample and the Downs sample has a t value of 2.239. A t value of this magnitude could not occur more than five times in a hundred on the basis of chance alone. Since the .05 level of confidence is the criterion for significance used in this report, the difference for facial angle readings between the Indiana sample and Downs' findings is significant at the .05 level and the null hypothesis rejected. The difference of 2.6° between facial angle readings for the Indiana sample and Riedel's report has a t value of 4.341. A t value of this magnitude would not occur more than one time in a thousand on the basis of chance alone. The null hypothesis is therefore rejected at the .001 level, and the difference is significant. On the Facial Skeleton Polygon, on which means and variations to two standard deviations on either side of the mean of both the Downs and Riedel readings are superimposed (Fig. 5), the mean of the Indiana sample will be seen to be on the retrognathic side as compared with the means of Downs and Riedel.

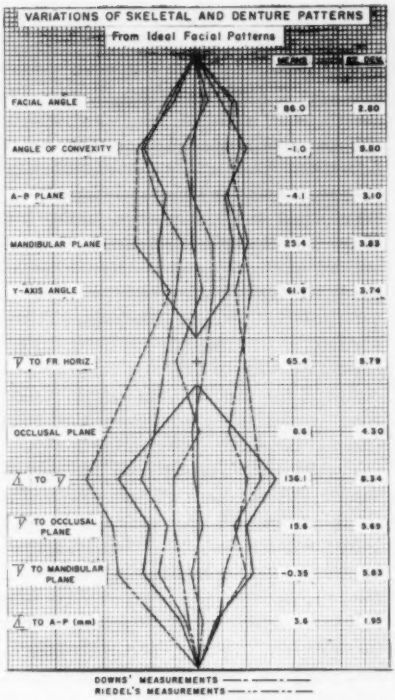


Fig. 5 Means and dispersions (two standard deviations on both sides of the mean) of the findings of the analyses of Downs and Riedel plotted on the facial polygon for the combined Indiana sample.

Angle of Convexity This group shows the greatest variability of any of the measurements of the skeletal pattern within the Indiana sample. The mean is -1.0°, which is smaller than the readings of either Downs (0.0°) or Riedel (+1.6°), but neither of the differences are significant. The difference between the Indiana sample and that of Downs (1.0°) has a t value of 1.164, which does not reject the null hypothesis at the .05 level. The difference of 2.6° between the Indiana group and that of Riedel has a t value of 0.716, which also does not reject the

null hypothesis at the .05 level.

The A-B Plane Angle The mean of the Indiana sample for this angulation is —4.3°. The difference of 0.5° between the readings for the Indiana sample and the Downs sample has a *t* value of 1.164. A *t* value of this magnitude does not reject the null hypothesis at the .05 level, therefore the difference is not considered significant. Riedel did not report the necessary data for this measurement to perform a test of significance. The standard deviation for the Indiana sample is ±3.10, compared with ±3.67 for Downs. The readings for the Indiana sample range from —10.5° to +4.5°, compared with Downs' ranges: —9.0° to 0.0°.

Frankfort Mandibular Plane Angle The mean of the Indiana sample for this angulation is 25.4°, compared with Downs' reading of 21.9° and Riedel's 26.2°. The difference of 3.5° between the readings for the Indiana group and Downs' reading has a *t* value of 0.967; the difference of 0.8° between the Indiana sample and that of Riedel has a *t* value of 0.598. In neither instance is the null hypothesis rejected at the .05 level of confidence, and the differences are therefore not considered significant. The standard deviation for the Indiana sample is ±3.83, for the Downs' sample ±3.24, and for Riedel's ±5.95

Y-Axis Angle The mean of the Indiana sample for this measurement is 61.8°, compared with readings for Downs of 59.4° and for Riedel 60.7°. The difference of 2.4° between the Indiana sample and that of Downs has a *t* value of 2.408. A *t* value of this magnitude could not occur more than two times in a hundred on the basis of chance alone. The null hypothesis is therefore rejected within the accepted criterion for significance, and the difference is significant at the .02 level. The difference between the Indiana sample and that of Riedel for this measurement, a difference of 1.1°, has a *t* value of 1.524. A *t* value of this magnitude does not reject the null hypothesis at the accepted level of confidence (.05) and the difference is therefore not significant. On the Facial Skeleton Polygon (Fig. 5), on which means and ranges of measurements from the Indiana sample are plotted, it will be seen that the mean of the Indiana sample for the Y-axis angle is disposed somewhat retrognathically in comparison with Downs' reading.

The Cant of the Occlusal Plane The mean of the Indiana sample for the occlusal plane angle is 8.6°, compared to readings of 9.3° for Downs' sample and 8.5° for Riedel's. The difference of 0.7° between the readings for the Indiana group and Downs' has a *t* value of 0.637. The null hypothesis is not rejected at the .05 level. The mean difference is not significant. Riedel did not report the necessary data to perform a significance test for this measurement. The standard deviation for the Indiana sample is ±4.30, compared with Downs' ±3.83. Within the Indiana sample, the mean difference between male and female readings is 1.6°. The *t* value is 0.261. The null hypothesis is not rejected at the accepted level of confidence, and the difference is not significant.

The cant of the occlusal plane, relating the slope of the occlusion to Frankfort horizontal, is conventionally placed in the list of dental measurements of the Downs' analysis. A careful examination of the measurements of this analysis for the fifty cases of the Indiana sample indicated that actually the occlusal plane angle tended to behave more in accordance with the activity of the skeletal structures than with the dental. To prove or disprove this impression, accordingly, a study of the correlations of the occlusal plane

angle was undertaken, in which this angle was correlated with every other dimension of the Indiana sample analysis according to the method of Downs. This study showed that the cant of the occlusal plane was more closely correlated with the skeletal measurements than with the dental reading. A significant correlation at the .001 level was obtained between the occlusal plane angle and the facial angle, mandibular plane angle, and the Y axis. Between this angle and the axial inclination of the lower incisor with the Frankfort plane a significant correlation at the .01 level was found and one at the .05 level with the inclination of the mandibular incisor to the occlusal plane.

Angulation of the Long Axes of Maxillary and Mandibular Central Incisors The mean for the Indiana sample is 136.1° Downs' reading is 135.4°. Riedel's is 131.0°. The difference of 0.7 between the readings of the Indiana sample and that of Downs has a *t* value of 0.349. The null hypothesis is not rejected at the accepted level of confidence, and the difference is not significant. The difference of 5.1° between the readings of the Indiana sample and that of Riedel has a *t* value of 2.889. A *t* value of this magnitude could not occur more than one time in a hundred on a basis of chance alone. Accordingly, the null hypothesis is rejected and the difference is significant at the .01 level of confidence. The Facial Skeleton Polygon (Fig. 5) illustrates how the Riedel mean is disposed retrognathically as compared with the mean of the Indiana group. The standard deviation of the Indiana sample is ±8.34, compared with Downs' ±5.76 and Riedel's ±9.24.

Maxillary and Mandibular Central Incisor Teeth Axial Inclinations Related to the Frankfort Horizontal The measurements of central incisor teeth axial inclinations to Frankfort plane are not strictly within the realm of the analysis according to Downs' method. Since the landmarks of Downs are used, and also because of the interest stimulated by Tweed regarding the positioning of the mandibular incisor tooth in relation to Frankfort plane, it was deemed reasonable to include these measurements. The necessary data to perform significance tests was reported neither by Downs nor by Riedel for the positioning of the mandibular central incisor tooth.

For the angulation of the long axis of mandibular central incisor tooth to the Frankfort plane, the mean of the Indiana sample is 65.4°, with a standard deviation of ±5.79. Downs reported a mean of 66.7°. Riedel's reading is 61.0°. Within the Indiana sample, the mean difference between male and females is 1.2°. The *t* value is 0.169. The null hypothesis is not rejected at the .05 level, and the difference is not significant.

For the angulation of the long axis of the maxillary central incisor tooth with the Frankfort plane, the mean of the Indiana sample is 109.2°, with a standard deviation of ±6.01. Riedel reports a mean of 111.0°, with a standard deviation of ±5.70. Downs' reading is 111.3°; he did not report the data necessary to perform a significance test. The difference of 1.8° between the means of the Indiana sample and Riedel's study has a *t* value of 1.544. The null hypothesis is not rejected at the .05 level, and the difference is not significant.

The Angulation of the Long Axis of the Mandibular Central Incisor Related to the Occlusal Plane. For this measurement the reading of the Indiana sample is 15.6°, compared with Downs' reading of 14.5° and Riedel's 20.6°. The difference of 1.1° between the Indiana group and Downs' has a

t value of 0.802. The null hypothesis is not rejected at the .05 level, and the difference is not significant. The difference of 5.0° between the Indiana sample and Riedel's has a t value of 4.108. A t value of this magnitude could not occur more than one time in a thousand on the basis of chance alone. The null hypothesis is rejected and the difference is significant at the .001 level.

The Angulation of the Mandibular Central Incisor to the Frankfort Mandibular Plane The mean of the Indiana sample for this measurement is —0.4°. Downs' reading is +1.4°; Riedel's is +3.1°. The difference of 1.8° between the means of the Indiana sample and Downs' has a t value of 1.308. The null hypothesis is not rejected at the .05 level and the difference is not significant. The difference of 3.5° between the readings of the Indiana sample and Riedel has a t value of 2.762. A t value of this magnitude could not occur more than one time in a hundred on the basis of chance alone. The null hypothesis is rejected and the difference is significant at the .01 level. The Facial Skeleton Polygon (Fig. 5) shows the retrognathic disposition of Riedel's mean in relation to that of the Indiana sample. The standard deviation for the Indiana group is ±5.83, for Downs' study ±3.48, and for Riedel's ±6.78.

The impression is that, in those cases exhibiting excellent occlusion and/or good facial patterns, the mandibular central incisor teeth will tend to be more or less upright with respect to the Frankfort mandibular plane. The findings of the Indiana sample confirm this general impression, but further suggest that there is a wide range of variability to be found, as indicated by the standard deviation of ±5.83° and the readings which range from —15.0° to +12.4°.

The Distance from the Incisal Edge of the Maxillary Central Incisor to the AP Plane The reading for the Indiana sample is 3.6 mm., compared with Downs' reading of 2.7 mm., and Riedel's 5.5 mm. The difference of 0.9 mm. between the means of the Indiana sample and Downs' study has a t value of 1.789. Since this could occur more than five times in one hundred on the basis of chance alone, the null hypothesis is not rejected and the difference is not significant at the level of confidence used as the accepted criterion of significance (.05). The difference of 1.9 mm. between the means of the Indiana sample and Riedel's has a t value of 3.654. A t value of this magnitude could not occur more than one time in a thousand on the basis of chance alone. Accordingly, the null hypothesis is rejected and the difference is significant at the .001 level of confidence. Fig. 5 shows the retrognathic disposition of Riedel's reading in comparison with that of the Indiana sample. This particular dimension has the smallest standard deviation, the smallest range of variation of any measurement considered in this report. The standard deviation of the Indiana sample is ±1.95; that of Downs' study is ±1.80, and Riedel's ±3.15.

Correlations Within the Indiana Sample Between Various Skeletal and Denture Measurements Used in Downs Analytical Method

An examination of polygons for the cases of the Indiana sample shows a tendency for certain of the dimensions to function in a compensatory or balancing manner in opposition to the movements of other dimensions. That is to say, where one measurement was, for example, to the right or prognathic side of the mean as seen on the polygon — especially if the divergence were relatively great — it would be balanced

by an equivalent discrepancy perhaps in the opposite direction of at least one other dimension.

To evaluate this tendency which had been observed by general perspection, it was deemed advisable to correlate those dimensions which most frequently seemed to function in the compensatory manner suggested.

(1) Between the facial angle and the Y-axis angle, there exists an inverse correlation of —0.500. The *t* value is 3.50. The null hypothesis is rejected and the correlation is significant at .01 level. The polygon is so constructed that the facial angle increases to the right or prognathic side of the mean line; the Y-axis angle decreases in that direction. This negative correlation suggests, therefore, that so far as the polygon-picture is concerned, the two angles will very often move in the same direction, although not necessarily the same degree.

(2) A coefficient of correlation of —0.909 exists between the facial angle and the Frankfort mandibular plane angle. The *t* value is 6.36. The null hypothesis is rejected and the correlation is significant at the .001 level of confidence. On the polygon, the Frankfort mandibular plane angle decreases to the right of the mean. The inverse correlation suggests that, as seen on the polygon, the two dimensions will very often move in the same direction with respect to the mean, again not necessarily the same degree.

(3) Between the Frankfort mandibular plane angle and the Y-axis, the coefficient of correlation is positive: +0.619. The *t* value is 4.33. The null hypothesis is rejected and the correlation is significant at the .001 level. On the polygon, both dimensions will be seen to increase in the same direction with respect to the mean. Since a significant positive correlation is present between these two measurements, it is suggested that they will often vary in the same direction.

(4) Between the angle of convexity and the A-B plane angle, a negative coefficient of correlation exists: —0.330. The *t* value is 2.30. The null hypothesis is rejected and the correlation is significant at the .05 level. Since the two measurements, as constructed on the polygon, increase in opposite directions from the mean, the significant inverse correlation indicates that the two dimensions will often vary in the same direction.

(5) The coefficient of correlation between the angle of convexity and the linear measurement of the maxillary central incisor tooth to the plane from Point A to pogonion is +0.279. The *t* value is 1.953. The null hypothesis is not rejected.

(6) Between the facial angle and the linear measurement of the lower border of the mandible (gonion to pogonion, which is not a landmark used in Downs' analysis), the coefficient of correlation is +0.344. The *t* value is 2.41. The null hypothesis is rejected and the correlation is significant at the .05 level of confidence. This significant positive correlation suggest that often, as the facial angle increases — as the profile tends to become flatter or more concave, the lower border of the mandible will increase in absolute size.

Comparison with Riedel's Analysis of Landmarks Related to the Sella-Nasion Plane

Sella-Nasion Plane to Point A The Indiana sample mean is 81.22°. The mean reported by Riedel is 82.01°. The difference between the means of 0.79° has a *t* value of 1.12. The null hypothesis is not rejected at the .05 level and the difference is not significant. Riedel's findings show a greater dispersion. The standard deviation reported by Riedel is ±3.89, compared with the

Indiana sample's ±3.11.

Sella-Nasion Plane to Point B. The Indiana sample mean is 79.79°. The mean reported by Riedel is 79.97°. The mean difference of 0.18° has a *t* value of 0.26. For this value of *t*, the null hypothesis is not rejected and the difference is not significant at the .05 level of confidence.

Difference Tests of significance, comparing the Indiana sample with Riedel's, can not be performed since Riedel did not report the necessary data. For the Indiana sample, the discrepancy or difference between the measurements of the sella-nasion plane with Point A and Point B is 1.42°. Riedel reports a reading of 2.04°. For the Indiana group, the standard deviation is ±2.17. The readings range from —4.0° to +7.1°.

Sella-Nasion Plane Related to the Maxillary Central Incisor For this measurement the mean for the Indiana sample is 105.0°. Riedel reports a reading of 104.0°. The value of *t* for the mean difference of 1.0° is 0.78. This value of *t* does not reject the null hypothesis and the difference is not significant at the .05 level. The standard deviation for the Indiana sample is ±6.98; for Riedel's sample, ±5.75.

Sella-Nasion Plane Related to Gnathion The mean for the Indiana sample is 80.5°; for Riedel's sample, the mean is 79.3°. The difference between the means of 1.2° has a *t* value of 5.284. The null hypothesis is rejected and the difference is significant at the .001 level of confidence. The Riedel reading is disposed retrognathically with relation to that of the Indiana sample. The Indiana sample shows greater dispersion: the standard deviation for the Indiana sample is ±3.79, compared with Riedel's reading of ±3.39.

Sella-Nasion Plane Related to Frankfort Mandibular Plane For the Indiana sample, the reading is 29.3°; for Riedel's sample, the reading is 31.7°. The mean difference of 2.4° has a *t* value of 2.27. The null hypothesis is rejected and the difference is significant at the .05 level of confidence. The dispersion is greater for the Indiana sample. The Indiana sample has a standard deviation of ±5.50 compared with ±5.19 for Riedel's sample.

Evaluation of Vertical Dysplasia

Linear Measurements. Table VI, a summary of the findings of the Indiana sample and those of Wylie and Johnson, shows that all readings of the Indiana sample, both linear and angular, are more widely dispersed than those of Wylie and Johnson.

Proportion of Total Face Height which is Upper Face Height. The mean difference of 1.7% has a *t* value of 3.66. The null hypothesis is rejected, and the difference is significant at the .001 level. The Indiana sample shows wider dispersion.

Gonial Angle. This angle is an anatomical entity whose dimension is defined relatively early in life and need not be expected to change appreciably with increase of age. The mean difference is not significant at the accepted level.

The Frankfort mandibular plane angle was correlated with certain denture and skeletal dimensions used in the vertical displacement study of Wylie and Johnson and in the Downs' analysis. The results of this study confirm the previous findings of Wylie and Johnson, with one exception which will be noted.

(a) As the Frankfort mandibular plane angle becomes steeper (increases in angulation), the total face height increases. The correlation is significant at the .02 level of confidence.

(b) As the mandibular plane angle becomes steeper, the percentage of lower face height to the total face height

TABLE VI

Mandibular and vertical height measurements used in the evaluation of vertical dysplasia: The findings of the Indiana sample and the study of Wylie and Johnson. With the exception of the gonial angle and the facial height proportions, all measurements are linear and reported in millimeters. Wylie and Johnson did not report ranges. Their study was undertaken on 47 children between the ages of 11 - 13 years, who were by subjective observation regarded as having good looking faces.

Measurement		*Mean*	*S.D.*	*Range*
Ramus Height	I	59.6	±5.88	48.2 to 73.1
	WJ	54.8	±3.80	
Gonial Angle	I	123.8	±6.25	110.5 to 138.6
	WJ	122.5	±4.80	
Lower Border Mandible	I	79.8	±4.76	70.0 to 90.9
	WJ	67.3	±3.09	
Total Face Ht.	I	121.63	±7.41	106.6 to 137.1
	WJ	113.00	±4.55	
Upper Face Ht.	I	55.1	±3.32	49.3 to 63.5
	WJ	50.7	±2.58	
Lower Face Ht.	I	66.6	±5.88	54.5 to 78.5
	WJ	62.4		
$\frac{\text{UFH}}{\text{TFH}} \times 100$	I	45.5	±2.34	40.0 to 50.8
	WJ	43.8	±2.18	
$\frac{\text{LFH}}{\text{TFH}} \times 100$	I	54.5	±2.26	49.2 to 60.0
	WJ	56.2		

increases. The correlation is significant at the .01 level.

(c) Mandibular plane angle varies inversely with the ramus height. The negative correlation is significant at the .001 level of confidence.

(d) The mandibular plane angle varies inversely with the angulation of the mandibular central incisor tooth to the mandibular plane. The negative correlation is significant at the .02 level. This shows, in other words, the tendency of the lower central incisor tooth to become more "upright" with an increase in Frankfort mandibular plane angulation.

(e) The Frankfort mandibular plane angle varies inversely with the facial angle. The negative correlation is significant at the .001 level.

(f) The mandibular plane angle varies directly with the Y-axis angle. The correlation is significant at the .001 level of confidence.

(g) The mandibular plane angle varies directly with the cant of the occlusal plane. The correlation is significant at the .001 level.

(h) The coefficient of correlation between the mandibular plane angle and the linear measurement of the lower border of the mandible (gonion to pogonion) is +0.021. The value of *t* is 0.15. The null hypothesis is not rejected at the .05 level of confidence, and the correlation is not considered significant. This does *not* confirm the observation of Wylie and Johnson who reported an inverse relationship.

The Assessment of Anteroposterо Dysplasia

Tests of significance comparing the findings of the Indiana sample with those of Wylie's study can not be performed since Wylie reported no data

TABLE VII

A summary of measurements listing the means observed in the assessment of anteropostero dysplasia, and compared with the standards of Wylie.

Wylie's original analysis was reported from a sample consisting of 45 boys, 11.5 years of age, and 48 girls, averaging 11.3 years of age. These were Class I malocclusions in the late mixed dentition stages.

	Length Mandible	Porion-Sella	Sella-Ptm	Ptm-6	Ptm-ANS	Unit Score	St. Dev.	Range
INDIANA SAMPLE:								
Male	117.0	24.7	16.4	21.3	60.0	—2.5	±4.95	—12.0 to +13.0
Female	114.6	21.7	17.1	18.7	57.0	+1.2	±4.18	—6.5 to +9.5
Combined	116.5	22.8	16.8	20.3	57.4	—0.85	±5.20	—12.0 to +13.0
WYLIE SAMPLE:								
Male	103.0	18.0	18.0	15.0	52.0	0.0		
Female	101.0	17.0	17.0	16.0	52.0	—1.0		

except the means. Wylie stressed, as a matter of clinical experience, that only a clear-cut, obvious discrepancy from his standards had clinical importance. From this point of view, the findings of the Indiana sample may be regarded as acceptable deviations from the Wylie male standard of 0.0 and the female standard of —1.0, as far as the means are concerned; but all readings have wide ranges of dispersion.

Table VII compares the findings observed in the Indiana sample with the standards established by Wylie. The unit score readings for the males is orthognathic: —2.5. The standard deviation is ±4.95. The standard error of the mean is 1.16. The range is from —12.0 to +13.0.

The unit score reading for the females is prognathic: +1.2. The standard deviation is ±4.18. The standard error of the mean is 0.77. The range is from —6.5 to +9.5.

The unit score reading for the combined sample is —0.85, which is orthognathic. The standard deviation is ±5.20. The standard error of the mean is 0.74. The range is from —12.0 to +13.0.

THE INDIANA SAMPLE: DISCUSSION OF SOME SPECIFIC CASES

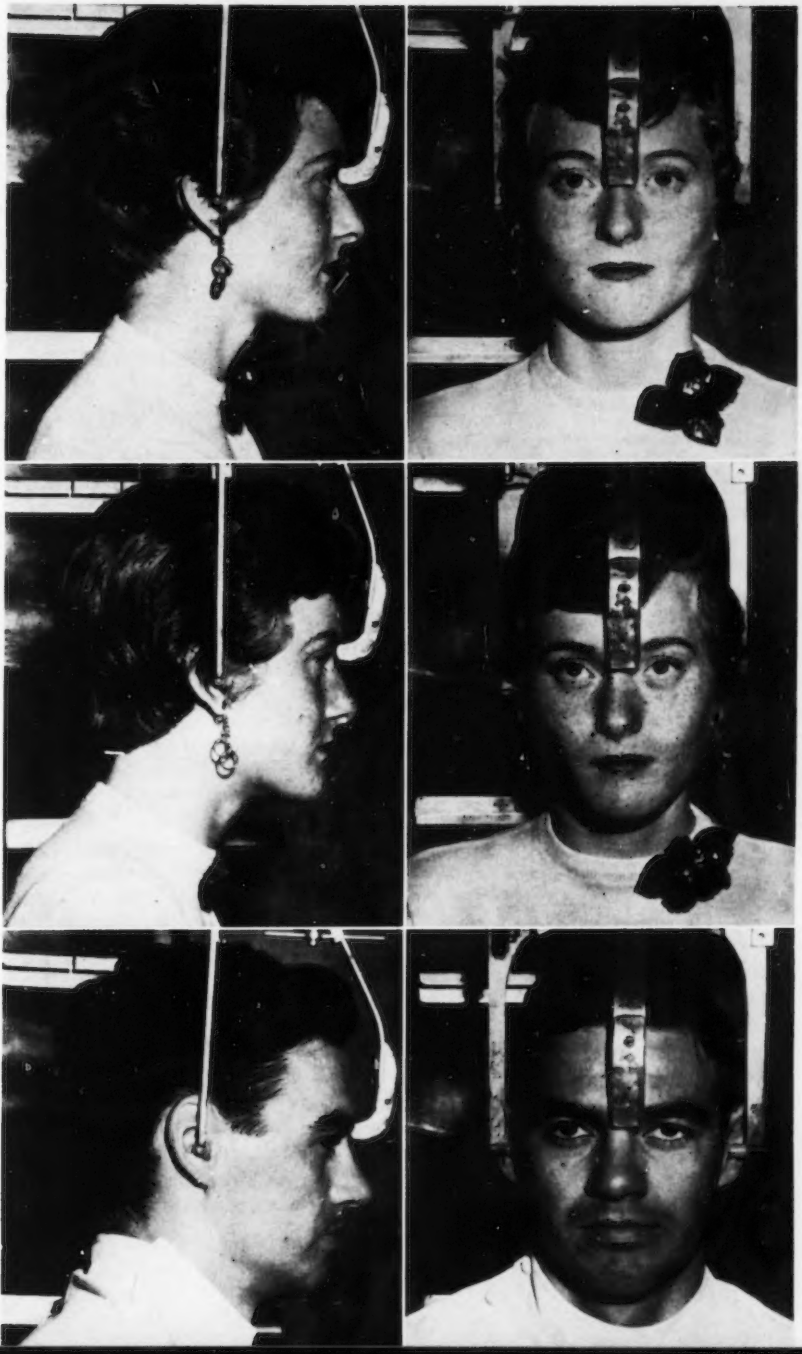
An opportunity is afforded for comparing a set of monozygotic female twins, seventeen years, nine months old, cases 2 and 3 (Fig. 6). None of the dimensions differ appreciably between these two cases, neither in the eleven measurements plotted on the polygons, the assessment of anteropostero dysplasia, the analysis against the sella-nasion plane, nor the vertical height studies.

The greatest differentiation occurs in the absolute linear measurements for certain dimensions of the mandible — the gonial angle, the lower border of the mandible (gonion to pogonion, and the absolute mandibular length) as measured for the anteropostero displacement analysis — and the total face height. But none of these differences can be considered conspicuous.

The mandibular length for Case 2 is 114.0 mm.; the lower border of the

→

Fig. 6 Above and center, photographs of monozygotic twins, cases 2 and 3. Below, case 22. This is an example of similar skeletal and denture readings with other cases in an altogether different type of face. The twins' faces are mesognathic while case 22 is more convex.



mandible measures 75.0 mm. For Case 3 these values are 109.5 mm. and 70.4 mm., well within the wide range of expected variability. At the same time, the Frankfort mandibular plane angle and the facial angle remain substantially the same. The gonial angle of Case 2 is greater than that of Case 3: 116.2° to 113.6°, but the standard deviation is ±6.25 for the entire sample and ±6.03 for the females. The total facial height for Case 2 is 109.8 mm., compared with 106.6 mm. for Case 3, a difference principally due to a slightly greater proportion of upper face height. But the small increase in absolute size of Case 2's dimensions is not conspicuous.

Case 22 is a male, twenty-four years, two months of age (Fig. 6). This individual, whose facial contours seem, on subjective appraisal, to be slightly on the convex or retrognathic side as compared with the straight or mesognathic profiles of the twins, displays startlingly similar readings in comparison with the twins, of all of the measurements summarized by the polygons (Fig. 7).

The greatest discrepancy, which may have some bearing on the profile contour, is to be found in the dimension relating the maxillary central incisor tooth to the plane from point A to pogonion, which is 5.5 mm., compared with the twins' readings of 3 mm. and 2 mm. But even this difference is within two standard deviations. The standard deviation for this reading is ±1.95.

As might be expected, the absolute linear size of anatomical structures is greater in the male (Case 22) than for the twins. However, the facial height proportions are not greatly at variance. In case 22, the percentage of lower face height to total face height is 55.4 per cent, compared with the twins' readings: 50.8 per cent and 51.2 per cent. The mean for this reading is 54.5 per cent; standard deviation is ±2.26. Thus, the face in Case 22 is disposed slightly more vertically, principally due to the greater lower face height, as compared with the twins.

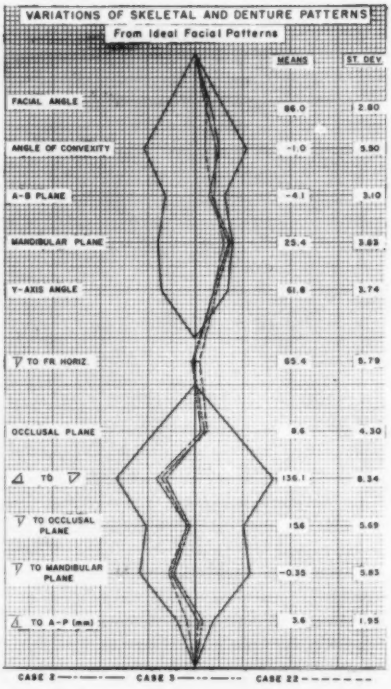


Fig. 7 Facial polygons of the twins in comparison with case 22.

Of all the measurements, the greatest discrepancy occurs in the assessment of anteropostero dysplasia. For the twins, the unit scores are +4.3 and +4.6; the score for Case 22 is —11.0.

This difference occurs because of the relative positioning of the head of the condyle and, more particularly, the maxillary first molar. The distance of these reference points from sella turcica and the pterygomaxillary fissure, respectively, is much greater in Case 22, where the high orthognathic unit score is but a reflection of the linear measurements.

The compensatory mechanism re-

sponsible for the overall excellence of the profile balance and proportion functions in two ways. The Y-axis angle and the facial angle are slightly prognathic (in relation to the mean values for these dimensions), thus placing pogonion in a relatively good relationship with respect to the facial plane. This, in conjunction with the prognathic (in relation to the mean) Frankfort mandibular plane angulation of 18° overcomes the orthognathic displacement in the anteropostero plane of space. At the same time, all polygon readings are well within the polygon limits (Fig. 7). The tendency of the skeletal measurements, including the occlusal plane angle, to be on the prognathic side of the mean is balanced by an equivalent tendency for the denture readings to be on the retrognathic side. The resulting facial patterns are in excellent overall balance.

Cases 9 and 43 illustrate an interest-

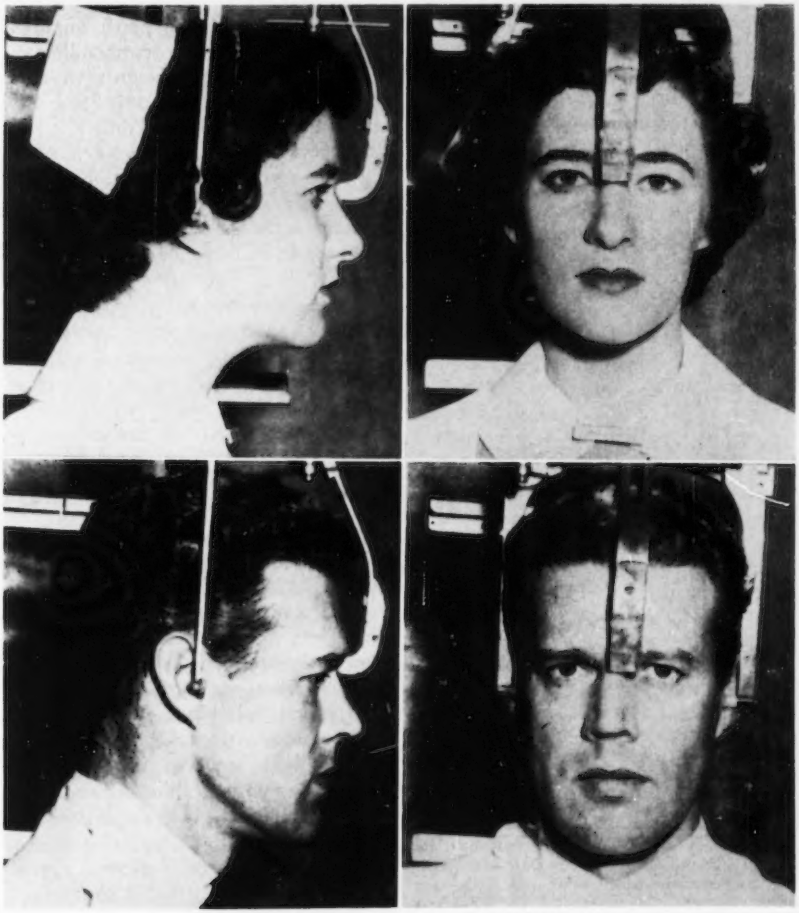


Fig. 8 Two examples of mesognathic faces,

ing contrast in dimensions within the straight or mesognathic facial type Fig. 8.

Case 9, a female nineteen years, eleven months of age is the person whose facial measurements most closely approximate the mean of every relationship investigated. This is true not only for the polygon measurements, but for all other dimensions considered (Fig. 9).

The mesognathic face of Case 43, a male thirty-six years, four months of age displays some interesting tendencies in comparison with Case 9. While the denture readings are well within the polygon limits, they are uniformly to the right (towards the Class III side)

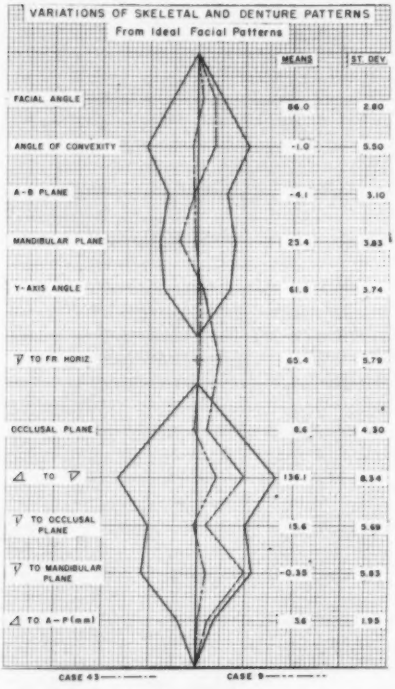


Fig. 9 Facial polygons for two cases having mesognathic faces compared with each other and with the means for the combined sample.

of the corresponding Case 9 readings. The denture measurements of Case 43 unmistakably imitate and parallel those of Case 9, but the contrasts between the dimensions are more marked, more exaggerated, as shown in Figure 9.

With regard to the skeletal readings, this imitative or parallel tendency is best illustrated on the polygon. The most conspicuous skeletal discrepancy is observed between the Frankfort mandibular plane readings: 29.2° for Case 43, and 26.0° for Case 9. The steeper Frankfort mandibular plane angle is accompanied by the corresponding increase in total facial height (which is not unexpected for the male), especially of the lower face. This is consistent with the previously noted positive and significant correlation between Frankfort mandibular plane angle and the percentage of lower to total facial height.

It would be expected that, in view of the negative correlation between the Frankfort mandibular plane angle and the facial angle, the steeper mandibular plane angle would be accompanied by a corresponding decrease in the facial angle. That this is usually true is attested by the coefficient of correlation of —0.909. In Case 43, however, the facial angle is 89.5°, as compared with the mean of the combined sample of 86.0° and the Case 9 reading of 87.0°. Since the standard deviation for this dimension is ±2.80, this difference takes on special importance. It would seem, therefore, that the facial angle in conjunction with the Y-axis angle and the readings for the angle of convexity and A-B plane, functions as a compensatory mechanism against the mandibular plane, so that, although the mesognathic face displays indices of profile contour to the right of the mean vertical line of the polygons, it remains in excellent general balance without showing tendencies toward concavity.

The unit score of anteropostero dis-

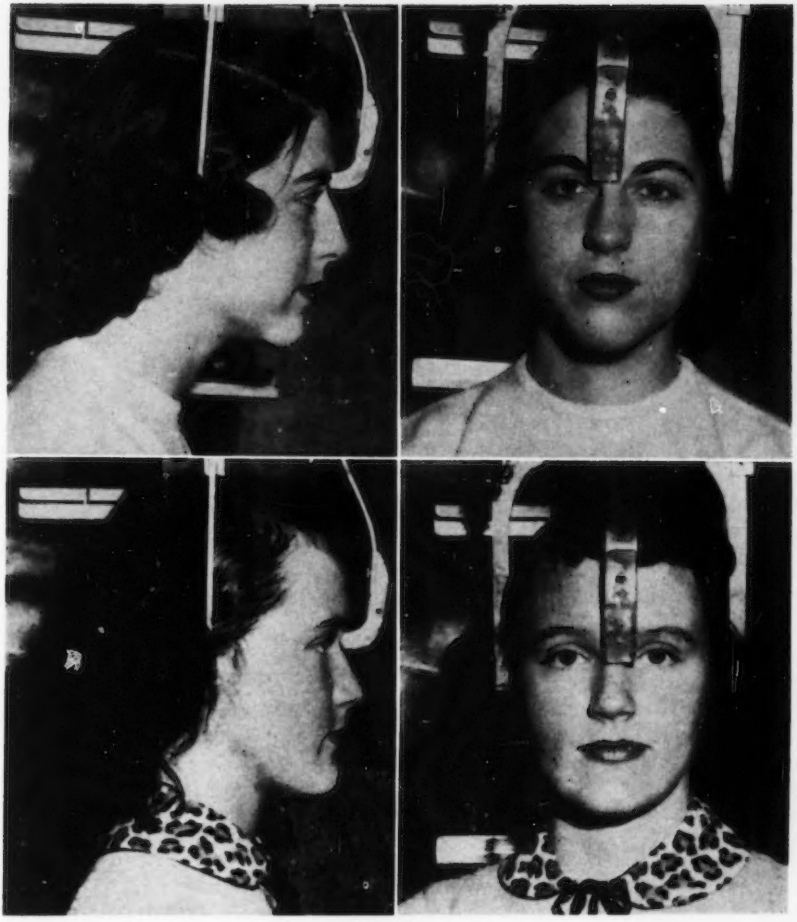


Fig. 10 Above, case 23, a convex face. Below, case 46, a concave face.

placement for Case 43 is +2.0 which from the point of view of clinical experience does not represent an important prognathic departure from the mean. This is another measurement, within the mesognathic facial type, with an ever-so-slight tendency toward the prognathic. The unit score for Case 9 is 0.0.

Cases 46 and 23, both females, afford an interesting contrast in two excellent faces subjectively rated as concave and convex, respectively, Fig. 10.

Case 23, the convex facial type, is twenty years, six months of age. Her skeletal and denture dimensions tend to fall to the left of the mean, as shown on the polygon (Fig. 11). But all readings are well within the polygonic limits. The score for anteropostero displacement is also well within the acceptable ranges, but shows a slight ten-

dency towards the orthognathic. The reading is —2.5, which is not a significant variation from the mean.

Case 46, the concave facial type, is fifteen years of age. This is the only person of the sample who is undergoing current orthodontic treatment. The malocclusion was of the Class III type; the orthodontic problem was primarily confined to the maxillary arch due to a relative lack of growth in the anterior segment of the maxilla with a consequent displacement of anterior dental units, particularly the upper cuspids. Here, a steep Frankfort mandibular plane angle is compensated by relatively high readings of the angle of convexity and the A-B plane angle toward the Class III side of the polygon. At the same time, the facial angle also falls on the Class III side of the mean, as does the Y-axis angle (Fig. 11). The concave tendency of this facial pattern is undoubtedly a result of the lack of development of the anterior portion of the maxilla, since a facial angle of 88° is reasonably close to the mean. It would be expected that if the Frankfort mandibular plane angle were not so steep, but more in accordance with the general tendencies of the other dimensions — toward the Class III side of the polygon, the facial appearance would be markedly prognathic. This disposition of dimensions should be correlated with the unit score for anteropostero dysplasia, which is +1.5, a score which suggests again the importance of an overall comparison of the anatomical structures in order to understand the definition of the facial pattern. The displacement of parts in such a slightly prognathic relation — the mean for females is +1.2 — is another indication of the effect of the compensatory mechanism functioning between the various parts (especially in view of the Frankfort mandibular plane reading of 30°) which often results in an excellent facial pattern in spite of extreme discrepancies in individual dimensions.

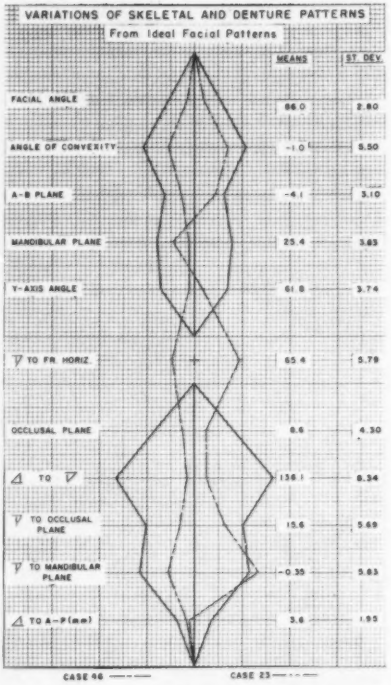


Fig. 11 Polygons of two cases showing contrast in readings between a concave (case 46) and a convex (case 23) type face.

The total facial heights of the two faces are similar: 120.0 mm. for Case 46 and 123.0 mm. for Case 23. The percentages of lower face height to total face height are also not at appreciable variance: 55.9 per cent for Case 46; 54.8 per cent for Case 23. This indicates how, in two different facial types exhibiting excellent overall balance and harmony, the profile proportions may be reasonably comparable even though considerable variation may be displayed with other dimensions.

With the exception of the measurement for maxillary central incisor tooth

to the A.P. plane which varies only .3 mm. from the mean, all the denture dimensions of Case 46 vary directly and in opposite direction (towards the Class III side) from those of Case 23. Their support of the general concave pattern is to be expected, as is, by contrast, the larger angulation, the less "uprightness", of the dentition of Case 23 in a convex face.

The obvious corollary to these observations is the general assumption that it is entirely conceivable and, indeed, logical that all three profile types — the concave, the convex, and the mesognathic or straight can and do occur in nature as ideal patterns with excellent balance and harmony.

Cases 31 and 38 (Fig. 12) have interesting and provocative characteristics in common for which a certain amount of speculation is justified.

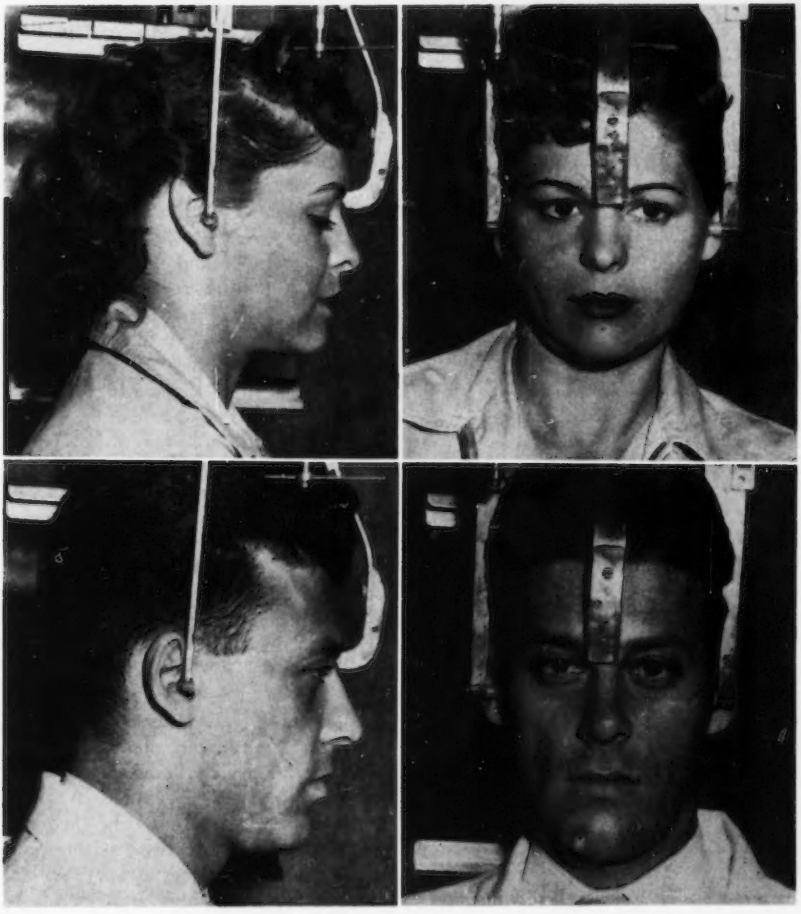


Fig. 12 Two individuals whose readings tend to be similar. The skeletal readings are uniformly excellent, being close to the mean line. Although these faces appear to be in excellent artistic balance, all denture readings, without exception, are very extreme, being on the Class II side of the polygon. Case 38, above; case 31, below.

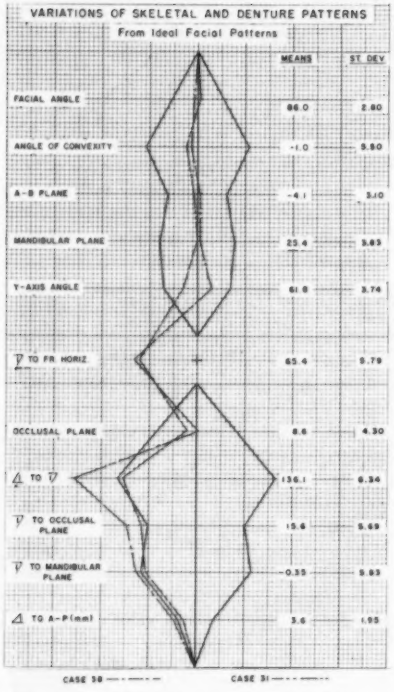


Fig. 13 Facial polygon for case 38 compared with case 31.

An examination of the polygons (Fig. 13) shows that the skeletal readings for both cases are close to the mean or well within the limits of acceptable deviations therefrom. The Case 38 skeletal readings are closer to the mean, but the difference is of no special importance; those of Case 31 tend to parallel these readings, with the greatest discrepancy showing in the Y-axis angulation. The occlusal plane angulation of both cases parallels the activity of the skeletal structures.

The curious features of these cases are in the denture patterns. Although both faces are in excellent general balance and all skeletal readings well within the acceptable ranges of variations, the denture patterns for both cases are extreme. This discrepancy is pronounced; except for the occlusal plane angle, all denture readings for Case 38 are beyond the limits of the polygon, on the left or Class II side; those of Case 31 either touch or are extremely close to the left or Class II limit of the polygon.

It must be mentioned here that the use of the term "denture readings" does not include, for purposes of interpretation, the measurement of the cant of the occlusal plane, whose curious tendency to function so often in a manner parallel with the direction of the skeletal measurements has already been noted.

Cases 38 and 31 illustrate the following maxim: the overall facial pattern may conceivably be excellent, provided the skeletal relationships are in excellent balance and proportion, even when the denture readings exhibit a wide scatter or dispersion. Thus, an excellent facial pattern may be defined with an astonishing degree of independence from the denture pattern or the disposition of the teeth.

A tendency for certain structures in the dentofacial complex to balance or compensate extremes in other dimensions to produce an overall balance and harmony in the general facial proportions has been previously noted. This compensatory property is illustrated in Cases 1, 15, 49, and 46, whose skeletal and denture polygons are shown in Figure 14.

It has been shown that there are high negative correlations between the Frankfort mandibular plane angle and the facial angle, and between the facial angle and the Y-axis angle. A study of the polygons will show the tendency of facial angle to decrease as the mandibular plane becomes steeper. At the same time, the Y-axis angle tends to increase. The compensatory mechanism is evidenced in those cases where, with

a high Frankfort mandibular plane angle, the facial angle and Y-axis angle remain close to the mean, or even to the right of the mean vertical line. The alternative compensation is for the A-B plane angle and the angle convexity to deploy to the right (or Class III side) of the mean.

For these individuals it has been suggested that the compensatory property acted through a reversal or minimizing of the correlations between the facial, Y-axis, and mandibular plane angles, in addition to the disposition of the angle of convexity and A-B plane angle to the right of the mean. With these cases, the denture readings, except for Case 1, generally are to the right of the mean, with the angulation of the mandibular central incisor tooth related to mandibular plane being extreme for Case 46 — on the Class III side of the polygon. In Case 46, the occlusal plane reading functions in an opposite direction from the mandibular plane angulation, reversing, in this case, the correlation. In Cases 1, 15, and 49, the occlusal plane readings, while not correlating exactly with the positive coefficient, remain, along with the Frankfort mandibular plane values, on the left of the mean vertical line.

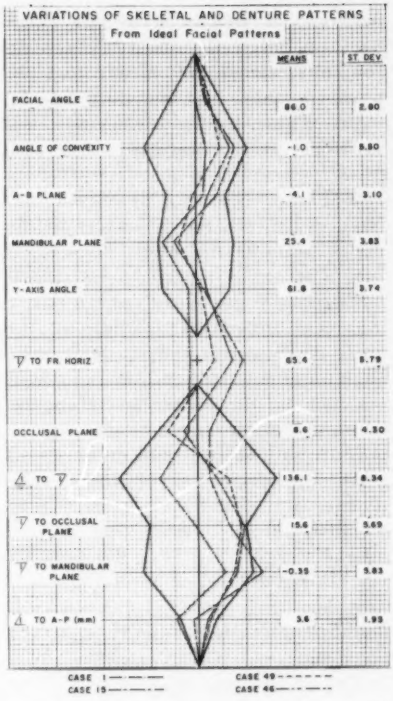


Fig. 14 Facial polygons: cases 1, 15, 49, 46.

Summary and Conclusions

1. An attempt has been made to evaluate, from lateral cephalometric roentgenograms, a sample of fifty excellent Caucasian faces, selected by a panel of artists because of the harmony of the facial balance and proportion. The opinions of the artists were remarkably uniform and included representative facial types ranging from the concave or prognathic, through the straight or mesognathic, to the convex or retrognathic.

2. A quantitative analysis was made, according to standardized cephalometric techniques, of the facial and denture patterns. Measures of central tendency and tests of confidence were established, as well as studies of dispersion in terms of the standard deviation, for each of the angular and linear measurements of the diverse anatomical dimensions.

3. The objective was further defined by studies of correlations and tests of significance of differences between males and females within the Indiana sample, and by comparisons with previous studies.

4. Means and ranges of variability to two standard deviations for the ten measurements used in the Downs' analysis and for the measurement relating the long axis of the mandibular central incisor tooth to the Frankfort

horizontal were plotted on the Facial Skeleton Polygons, constructed for the combined sample of fifty cases, the nineteen males, and the thirty-one females. The polygons are a convenient yardstick for comparison with other cases.

5. There were no significant differences between the males and the females in any of the measurements.

6. The males tended to be slightly more concave in skeletal pattern due to the more prognathic readings of the angle of convexity and the A-B plane angle; on the other hand, this was compensated by the higher facial angulation and smaller Y-axis of the females.

7. In both skeletal and denture patterns, the dispersion of the female readings was either almost identical or definitely broader than that of the males.

8. In the assessment of anteropostero dysplasia, the male unit-score was slightly more orthognathic than that of the female, but the difference was not statistically or clinically significant, and the ranges of variability were wide.

9. In the analysis according to the method introduced by Downs, the measurements of the Indiana sample were similar to those of Downs with the exception of the facial angle and the Y-axis angle where significant differences do exist. The range of extreme of all measurements of the Indiana sample is wider than that of Downs; all of Downs' denture measurements, as well as the Frankfort mandibular plane angle and the angle of convexity, have smaller standard deviations than those of the Indiana group.

10. The facial angle and the Y-axis angle of the Indiana sample were disposed slightly toward the retrognathic or Class II side of Downs' findings.

11. In the analysis according to the technique suggested by Downs, the findings of the Indiana sample were significantly different from those of Riedel in the facial angle, and in all readings of the denture pattern, with the exception of the measurement relating the maxillary central incisor tooth to the Frankfort horizontal. Riedel reported a wider dispersion in terms of standard deviation than those of the Indiana sample in all measurements with the exception of the angle of convexity, the Y-axis angle, and the relationship of the maxillary central incisor tooth to Frankfort horizontal.

12. As compared with the findings of Riedel, the facial angle of the Indiana sample was disposed retrognathically, while those denture readings significantly at variance with those of Riedel were disposed prognathically.

13. A study of the correlations between the occlusal plane angle and other measurements of skeletal and denture patterns shows that the occlusal plane angle is more closely correlated with the measurements of the skeletal pattern, rather than with those of the denture pattern, thus tending in most cases to imitate the activity of the skeletal pattern.

14. The role of the teeth in esthetics is difficult to define or assess as shown by the wide variability displayed by all denture readings. The broad dispersion of measurements of the denture pattern, as compared with those of the skeletal pattern, suggests that an excellent face is less dependent upon the denture, or that the denture pattern, in itself, is too variable and diversified an entity to be labelled of paramount importance in the maintenance of excellent facial pattern in untreated cases.

15. The hypotheses of Tweed and his followers regarding mandibular incisor positioning as index of facial esthetics cannot be substantiated in this sample of untreated cases in view of the liberal dispersion and variability of the read-

ings, i.e., while the mean of the Indiana sample for the angulation of the mandibular central incisor tooth to Frankfort plane was 65.4° (which compares favorably with Tweed's finding of 65.0°) the standard deviation was ±5.79, with readings ranging from 52.4° to 75.0°.

16. In the appraisal of landmarks measured against the sella-nasion plane (S-N), the findings of the Indiana sample differed significantly from those of Riedel's analysis in two measurements: S-N to gnathion and S-N to mandibular plane. In comparison with the findings of the Indiana sample, Riedel's measurements were disposed retrognathically. The dispersion was wider for the Indiana sample in all measurements except S-N to Point A and S-N to Point B.

17. Significant coefficients of correlation derived from the Frankfort mandibular plane angle and various skeletal and denture measurements used in the evaluation of vertical dysplasia according to the technique devised by Wylie and Johnson show that, as this angle becomes steeper (increases), the facial angle becomes smaller, the Y-axis angle increases, the gonial angle becomes larger, the ramus height decreases, the total face height — especially the lower face — increases, and the angulation of the mandibular central incisor teeth to the Frankfort mandibular plane decreases. This confirms the previous report of Wylie and Johnson.

18. There is some indication that a compensatory mechanism or balancing property functions within the dentofacial complex. This property exists in order to preserve the overall harmony and proportions of the facial pattern. Where one dimension shows an obvious discrepancy, one or more of the others will compensate by varying in such a way as to minimize the expected pattern of activity suggested by significant correlations with the dimension displaying the obvious deviation from the mean.

19. The sample used in this project is of special interest because of the varied facial types represented — a kaleidoscope of Caucasian facial types and of variations in measurements and relationships. Since the cases are, with one exception, untreated, they may be considered as being essentially anatomically stable, as compared with an equivalent number of treated cases. Yet, tremendous variation is demonstrated here.

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Integumental Contour And Extension Patterns

CHARLES J. BURSTONE, D.D.S., M.S.*

Indianapolis, Indiana

Superimposed upon a dentoskeletal framework lies a variable soft tissue mass comprising epithelium, connective tissue, and muscle. Variation in this soft tissue veneer can be an important factor in case analysis, as it influences: (1) facial form and esthetics, (2) muscle balance of the orbicularis oris complex and hence, the stability of the anterior dental segment.

In considering soft tissue, a number of approaches are possible. Methods of measuring superficial facial contour and the establishment of standards based on these methods can be presented.[1,2] Similarly dentoskeletal standards can be established from samples selected by esthetic criteria.[3] This investigation is concerned with two problems: (1) direct measurement of the soft tissue mass and, (2) differences in integumental contour and extension with respect to sex and maturation.

ACCEPTABLE FACE SAMPLES

Two samples, which possessed good or excellent facial profiles, were selected from a group of photographs by a panel of artists.* The only criteria for selection were age, race (Caucasian), and facial form. The younger age sample represented an adolescent group with a mean age of 14.7 years and a range from 13.4 to 15.6. This includes an age range at which orthodontic treatment is terminated in many instances. The second sample, a young adult group, possessed a mean age of 23.8 with a range from 16.5 to 36.3. In terms of orthodontic treatment, this sample reflects the post-retention period. The broad age range of the young adult sample might be criticized, but this criticism could be partly tempered by the knowledge that growth changes are not as marked in this group as they would be in a younger age.

The number in each sample and its distribution by sex is given in Table I.

TABLE I

Adolescent		*Young Adult*	
Male	11	Male	15
Female	26	Female	25
Total	37	Total	40

The reliability of artists choosing a sample of this type might be questioned. Perhaps, their esthetic criteria do not represent the criteria of the general population. With this in mind, the adolescent sample was rechosen by a group of housewives. There were no differences in opinion concerning faces that both housewives and artists had typed "excellent". The only difference occurred in the "good" face category. These substitutions were small in number and did not appreciably alter any of the mean values that were later determined. This tended to reaffirm the sampling procedure.

The faces of both samples are minimally interpreted and are referred to as "acceptable" rather than "good" or "excellent".

*Director of Orthodontics, Indiana University School of Dentistry.

*John Herron Institute of Art, Indianapolis, Indiana.

Method of Integumental Extension Measurement

The basic record for the study was the lateral headplate, which was taken using the Broadbent technique.[4] The cassette was placed as close as possible to the subject. The lip posture was that of initial closure, with the mandible in centric position.

The development of a consistent, accurate, and meaningful method of measurement of the soft tissue mass presents inherent problems. These problems particularly arise in the dimension describing "thickness". The soft tissue of the face is quite irregular and variable and does not readily suggest planes of reference within the soft tissue itself and, therefore, if such planes are to be established, they must utilize dental or skeletal landmarks. There is a lack of uniform correspondence in a vertical plane between skeletal and soft tissue landmarks (standard deviations may be as large as 3 millimeters). Hence, simple lines connecting soft and hard tissue landmarks would cross the soft tissue at various angles and would not accurately reflect lip thickness.

A compromise method was adopted, which measures the amount of extension of integumental landmarks from adjacent skeletal points relative to one common plane. Since these measurements do not exactly reflect "thickness" and "length", they are best referred to as horizontal and vertical extensions. The common plane of reference for horizontal extension measurements is the nasal floor, and for vertical extension measurements, a perpendicular to the nasal floor is utilized.

Horizontal extension (Fig. 1A) represents the distance in millimeters between a dental or skeletal landmark and an integumental landmark as measured along the nasal floor (a line connecting anterior and posterior nasal spines). Seven horizontal extension readings are listed below and the dental or skeletal (S) and integumental (I) landmark for each is operationally defined.

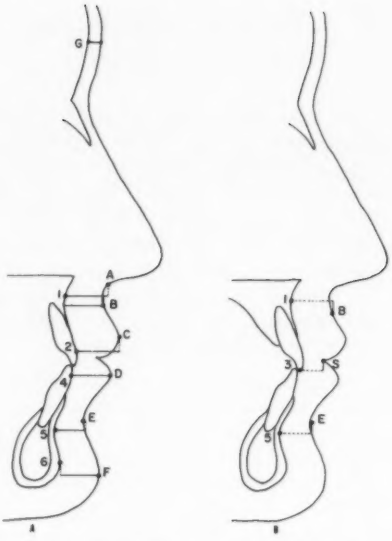


Fig. 1 Integumental and skeletal landmarks demonstrating extension measurements. A, horizontal extension, B, vertical extension. Skeletal landmarks: 1) subspinale, 2) incision superius, 3) incision superius, 4) incision inferius, 5) supramentale, 6) pogonion. Integumental landmarks: A) subnasale, B) superior labial sulcus, C) labrale superius, D) labrale inferius, E) inferior labial sulcus, F) menton, G) glabella, S) stomion.

Glabella (I) — det rmined by a tangent to the forehead from a line passing through subnasale.
Glabella (S) — the intersection of the outer plate of the frontal bone with a h rizontal line (parallcl to nasal floor) drawn from frontal point (1).
Subnasale (I) — the point where maxillary lip and nasal septum form a definite angle. If the depression is a gentle curve, subnasale is interpreted as the most concave point in this area as measured by a line angled 45 degrees from nasal floor.
Subspinale (S) — the deepest point between anterior nasal spine and prosthion relative to nasal floor.
Superior Labial Sulcus (I) — the deepest point on the upper lip as determined

by a line drawn from subnasale inclined so that it forms a tangent with labrale superius.
Subspinale (S) — the deepest point between anterior nasal spine and prosthion relative to nasal floor.
Labrale Superius (I) — the most prominent point on the upper lip as measured from a perpendicular to nasal floor.
Incision Superius (S) — the most prominent point on the maxillary incisor as determined by a tangent to the incisor passing through subspinale.
Labrale Inferius (I) — the most prominent point on the lower lip as determined by a perpendicular from nasal floor.
Incision Inferius (S) — the most anterior point on the lower incisor determined from a line tangent to the chin and mandibular incisor.
Inferior Labial Sulcus (I) the most concave point as measured by a line tangent to menton and labrale inferius.
Supramentale (S) — deepest point between pogonion and infradentale as determined from a line tangent to lower incisor and pogonion.
Menton (I) — most anterior point on chin determined by a line tangent to the lower lip and the chin.
Pogonion (S) — most anterior point on the chin as determined from a perpendicular to nasal floor.

Vertical extension (Fig. 1B) is the distance in millimeters between a dental or skeletal and integumental landmark measured along a perpendicular to nasal floor. If the integumental point is superior to the dental or skeletal one, the reading is given a plus sign; if inferior, a minus sign.

Superior Labial Sulcus —(I) — the deepest point on the upper lip as determined by a line drawn from subnasale inclined so that it forms a tangent with labrale superius.
Subspinale (S) — the deepest point between anterior nasal spine and prosthion relative to nasal floor.
Inferior Labial Sulcus (I) — the most concave point as measured by a line tangent to menton point and labrale inferius.
Stomion (I) — the juncture in the midline of the upper and lower lips.
Supramentale (S) — deepest point between pogonion and infradentale as determined from a line tangent to lower incisor and the chin.
Incision Superius (S) — the most inferior point on the maxillary incisor.

Integumental Extension Standards

The preceding method of integumental extension analysis was applied to the adolescent and young adult samples. Means, standard deviations, and standard errors of mean by sample and sex are given in Tables II and III.

The soft tissue mass of the face lying inferior to subnasale is quite thick in comparison to the mass of the glabellar

TABLE II

Integumental Extension Values of Acceptable Adolescent Profiles

	MALES			*FEMALES*			
Extension Measurements	*Mean*	*S.D.*	*S.E. of Mean*	*Mean*	*S.D.*	*S.E. of Mean*	*P**
Glabella	7.0	1.11	0.37	6.6	0.82	0.16	.20
Subnasale	18.7	2.33	0.78	16.9	1.45	0.29	.05
Superior Labial Sulcus	16.2	1.61	0.54	14.7	1.88	0.38	.05
Labrale Superius	15.5	1.88	0.63	12.1	1.83	0.37	.001
Labrale Inferius	16.1	1.54	0.51	13.4	1.29	0.26	.001
Inferior Labial Sulcus	12.9	2.20	0.73	11.6	1.31	0.26	.05
Menton	12.8	2.19	0.73	12.2	1.85	0.37	.20
Subspinale-Superior Sulcus	—4.4	1.90	0.63	—3.4	1.78	0.36	.20
Supramentale-Inferior Sulcus	1.3	1.69	0.56	1.6	1.94	0.39	.20
Incision-Stomion	3.1	2.21	0.74	3.5	1.64	0.33	.20

* t test

region. This difference, in part, reflects the high degree of development of the orbicularis oris complex. The upper lip gradually becomes thinner as one moves from subnasale to labrale superius. The horizontal extension at inferior labial sulcus and menton is less than any other region of the lower face.

Vertical extension averages indicate that superior labial sulcus lies inferior to subspinale and inferior labial sulcus lies superior to supramentale. Stomion is positioned about three millimeters superior to the tip of the maxillary incisor.

Considerable variation in horizontal and vertical extension values is observed in the adolescent and young adult samples. However, the greatest variation is found in the lower face, particularly in the lips.

Correction of these linear values for enlargement has not been considered desirable. Most clinicians, who might find it useful to apply soft tissue standards would not consider it practical to use correction scales. The similarity in position of landmarks in respect to the central x-rays and the small linear dimensions tend to minimize error in the comparison of an individual to the standard.

To facilitate extension analysis, a grid based upon the adolescent acceptable profile sample is presented (Fig. 2). The grid is divided into two portions with male values at the top and female at the bottom. Mean values are listed above each measurement along the center line. Readings greater than the mean are plotted to the right and those less to the left. Standard errors of the mean and standard deviations are listed respectively at the right and left.

Integumental Extension Variation In Malocclusions

Malocclusions exhibit not only malrelations of teeth but also facial disharmony. In part, this disharmony may be produced by variation in the soft tissue mass. In many instances, the reverse will occur; soft tissue variation masks a dentoskeletal discrepancy.

If an individual is compared with an appropriate age and sex integumental extension standard, absolute values and

TABLE III

Integumental Extension Values of Acceptable Young Adult Profiles

	MALES			*FEMALES*			
Extension Measurements	*Mean*	*S.D.*	*S.E. of Mean*	*Mean*	*S.D.*	*S.E. of Mean*	*P**
Glabella	6.2	1.01	0.280	6.1	0.78	0.156	.20
Subnasale	19.3	1.74	0.482	15.5	1.64	0.328	.001
Superior Labial Sulcus	17.2	1.83	0.507	13.8	1.44	0.288	.001
Labrale Superius	15.1	1.92	0.532	11.8	1.54	0.308	.001
Labrale Inferius	16.3	1.45	0.402	13.4	1.68	0.336	.001
Inferior Labial Sulcus	11.9	1.24	0.344	10.9	1.10	0.220	.02
Menton	13.6	1.82	0.505	11.6	1.35	0.276	.001
Subspinale-Superior Sulcus	—6.2	2.08	0.576	—4.5	1.36	0.272	.01
Supramentale-Inferior Sulcus	1.1	3.21	0.890	2.5	1.52	0.304	.05
Incision-Stomion	2.3	2.56	0.709	3.7	1.68	0.336	.05

* *t* test

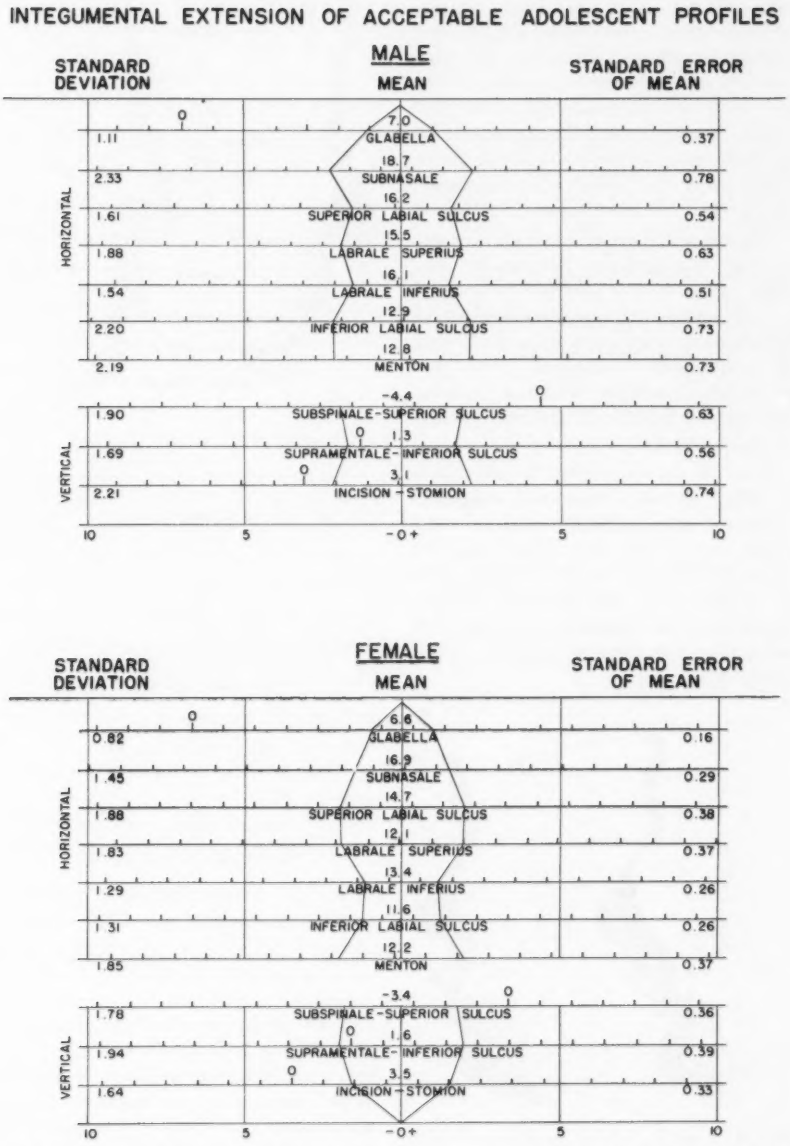


Fig. 2 The grid is divided into two portions by sex, male values at the top, female at the bottom. Mean values are listed above each measurement along the center line. Readings greater than the mean are plotted to the right and those less, to the left. Standard errors of the mean and standard deviations are listed respectively at the right and left.

their distance from the mean are not as important as the relationship of one value to another. Considering the relationship of one value to another, readings may deviate uniformly from the mean (cancellation of variation) or readings may deviate in opposite directions from the mean (accumulative variation).

Four cases are shown which present varying integumental extension patterns (Figs. 3, 4, 5 and 6). In case A, a large amount of maxillary horizontal extension is contrasted by a deficiency of mandibular extension. The accumulative variation between superior and inferior labial sulci should be noted (Figs. 3 and 4).

Case B demonstrates accumulative variation between horizontal extension values of subnasale and menton (8.7 millimeters). This soft tissue variation minimizes the total facial convexity that is inherent in the skeletal pattern. Superior labial sulcus lies considerably inferior to its normal position (Figs. 3 and 4).

Fig. 3 Case A, a large amount of maxillary horizontal extension is contrasted by a deficiency of mandibular extension. Case B, demonstrates accumulative variation between horizontal extension values at subnasale and menton (8.7 mm.).

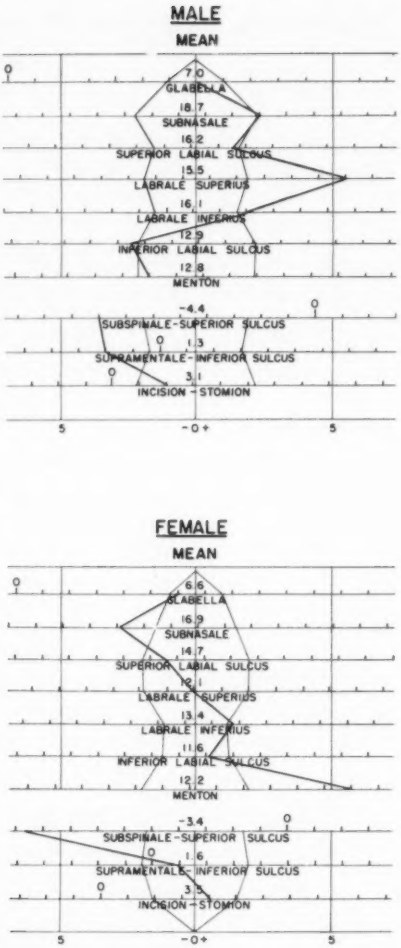
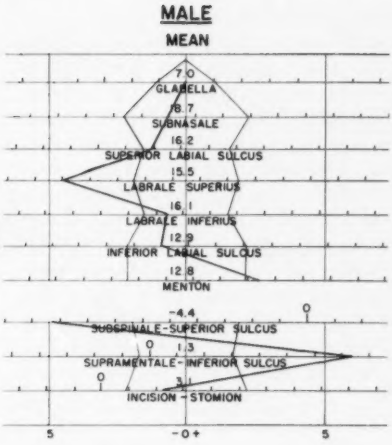


Fig. 4 Values from case A, above, and B, below, are plotted on grid.

A boy with a repaired unilateral cleft of the lip is seen in Case C. Lip mass has been noticeably reduced, especially in the region of labrale superius. Labiomandibular contour is benefited by decreased horizontal extension at labrale inferius and increased extension at menton. Superior and inferior sulci are atypically positioned in the vertical

Fig. 5 Case C demonstrates a repaired unilateral cleft of the lip. Case D, the profile possesses slightly greater horizontal extension than the standard in the maxillary region. Extremely small amounts of soft tissue extension are seen around the inferior labial sulcus and menton.



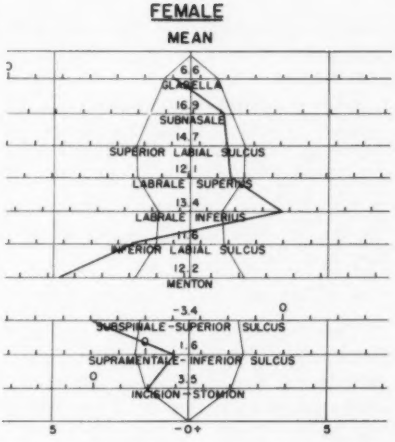


Fig. 6 Values from case C, above, and D, below, are plotted on the grid.

plane (Figs. 5 and 6).

The profile in case D possesses slightly greater horizontal extension than the standard in the maxillary region. The increased value of labrale inferius can be partly attributed to deflection of the lower lip produced by the overjet. Extremely small amounts of soft tissue extension are seen around the inferior labial sulcus and menton (Figs. 5 and 6).

In evaluating extension variation, particularly in the horizontal plane, a number of factors have to be considered. Not all of the variation need be produced by inherent structural variation in the soft tissue mass. For example Fig. 7 demonstrates two individuals with the mandible in centric position. The dotted line indicates soft tissue form with the lips relaxed and the solid line represents a closed lip position. In case B, little space is present between the lips in their relaxed state (interlabial gap equals 1 millimeter). By contrast in case A, the patient exhibits a large interlabial gap (12 millimeters) associated with a vertical labial insufficiency. In an effort to produce lip closure a marked effort is required. The ensuing muscular imbalance alters the soft tissue extension pattern. Likewise, in excess lip length cases (vertical

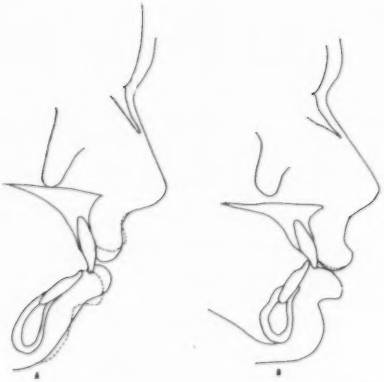


Fig. 7 Integumental extensions as influenced by postural variation: relaxed lip position — dotted line, initial lip closure — solid line, A) marked soft tissue change associated with vertical labial insufficiency, B) minimal change in soft tissue mass.

labial redundancy) the lips will protrude and thereby increase the extension pattern.

Some variation is associated with the method itself. Changing planes of reference (used for measurement and selection of landmarks) and variation in the relative position of landmarks should be considered as a possible source of variation.

Sex Differences In Extension

The soft tissue mass of the face demonstrates sex differences which are reflected in both adolescent and young adult samples, but are most marked in the latter. (Tables II and III)

In the young adult sample, there is no apparent difference between the sexes in the thickness of soft tissue covering the forehead. By contrast, in the lower face where the development of the orbicularis oris complex exerts its influence, significant differences are to be found. The soft tissue mass of all areas from subnasale to menton are thicker in the male. In particular, horizontal values in the upper lip average three to four millimeters greater in the male than in the female.

Vertical differences in the upper lip can be observed with respect to the skeletal points, subspinale and incision. In the male, superior labial sulcus and stomion are found to be in a more inferior position.

Maturation Changes in the Integumental Profile

The maturation of integumental extension and contour from the adolescent to the young adult has been studied on a cross-sectional basis utilizing two acceptable face samples. This type of procedure is useful in detecting unidirectional changes but tends to mask bidirectional variation. This, added to the danger of sampling error, suggests that these cross-sectional studies should be followed by longitudinal ones.

Considering horizontal extension (even though some significant differences can be demonstrated), the levels of confidence and the small magnitude of the mean differences suggest that longitudinal methods could best study the problem.

In the direction of vertical extension, it is seen that superior labial sulcus becomes more inferior in its relation to subnasale with age (Male: p .05, Female: p .02).

A method for measuring the integumental profile by angular means has been previously described. Readings are of two types: inclination angles, (profile components relative to nasal floor) and contour angles (profile components relative to each other).[2]

Table IV gives the means, standard deviations and probabilities for the two samples. For graphic purposes, the means of the *adult* sample are plotted on the *adolescent* grid (Fig. 8).

Lower facial inclination is significantly greater in the adolescent group. This is true for both anterior

and posterior measurements. Mandibular and interlabial inclinations are similarly greater in the younger age period. This difference could be partly explained by an increase in the mandibular prominence as part of the maturation process.

The protrusion of the upper lip from the sulcus (superior labial inclination) increases with age as contrasted with the curl of the lower lip (inferior labial inclination) which shows a significant decrease in the young adult sample. The prominence of the chin from the inferior sulcus shows an increase in the older group.

With reference to the contour angles of the face a significant difference is seen in only one, total facial contour. The total face becomes less convex with maturation.

Even though many inclination angles in the lower face demonstrate significant differences, contour angles formed in this area do not show significant differences. Labiomandibular contour remains fairly constant. Cross-sectional studies in younger age groups further suggest that the labiomandibular angle changes minimally with growth and maturation.[5] Maxillomandibular contour, a measurement of facial convexity below the nose, demonstrates no significant difference. It appears, therefore, that there is no evidence to suggest marked flattening of the lower face in the post adolescent period.

Since the significant differences (or their lack) between the two samples represent average maturation changes, individual variation is not taken into consideration. Hence, attempts to estimate individual integumental changes on the basis of these generalizations

TABLE IV

INTEGUMENTAL PROFILE MEANS AND STANDARD DEVIATIONS FROM ADOLESCENT AND ADULT SAMPLES, AND PROBABILITIES

	Adolescent		*Adult*		
Angle	*Mean*	*S.D.*	*Mean*	*S.D.*	*p**
(XAG) Upper Facial Inc.	—5.7	3.5	—6.5	3.2	above 0.05
(XAF) Lower Facial Inc.	8.2	4.0	4.8	4.0	0.01
(XBE) Lower Facial Inc.	15.3	4.8	11.7	4.2	0.01
(XAC) Maxillary Inc.	—2.2	7.6	—4.0	6.7	above 0.05
(XDF) Mandibular Inc.	11.5	5.5	7.5	5.5	0.01
(XCD) Interlabial Inc.	11.7	5.0	8.0	5.0	0.01
(XAB) Subnasal Inc.	17.1	7.0	16.0	7.4	above 0.05
(XBC) Superior Labial Inc.	—22.6	8.7	—27.0	9.5	0.05
(XDE) Inferior Labial Inc.	47.5	9.6	41.9	9.2	0.02
(XEF) Supramental Inc.	—12.9	6.5	—16.1	3.7	0.01
(GAF) Total Facial Con.	13.9	3.8	11.3	4.1	0.01
(ACDF) Maxillo-Mandibular Con.	13.5	8.9	11.5	6.5	above 0.05
(CDF) Labio-Mandibular Con.	0.2	7.0	—0.5	6.0	above 0.05
(ABC) Maxillary Sulcus Con.	39.7	9.8	43.1	10.0	above 0.05
(DEF) Mandibular Sulcus Con.	59.7	11.4	58.0	11.7	above 0.05

*p — .05 or less denotes significant differences between adolescent and adult integumental angles.

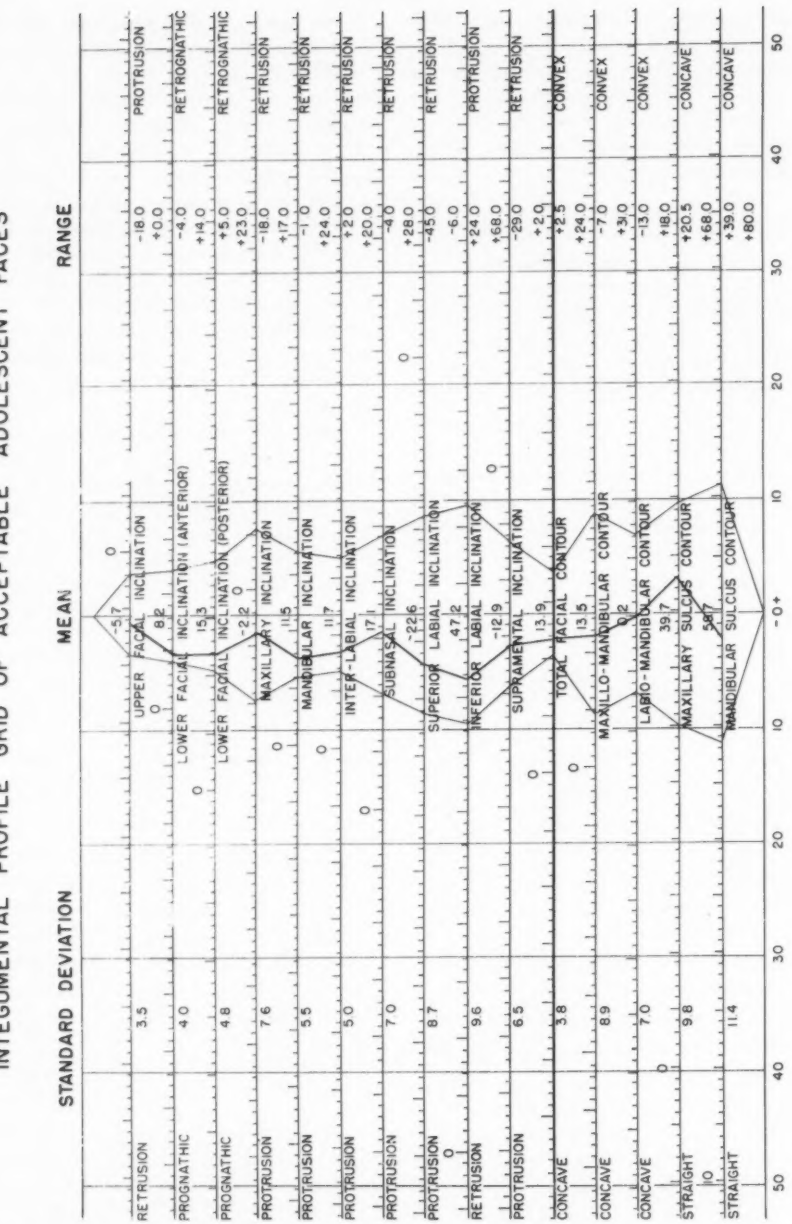


Fig. 8 Young adult profile mean values plotted on grid of acceptable adolescent faces.

should be made with considerable reservation.

Discussion

An awareness of integumental extension and contour is an essential element of case analysis. Since considerable variation may occur in the soft tissue mass of the face, treatment based on arbitrary dentoskeletal standards cannot be expected to consistently produce desirable facial form. In many individuals application of an absolute standard will lead to increased facial disharmony or the substitution of one type of disharmony for another. Since the soft tissues as well as dentoskeletal structures demonstrate variation, both should be considered in establishing the anteropostero-positioning of the denture and the axial inclinations of the anterior teeth.

Concomitant with hard tissue changes during treatment, a redistribution of soft tissue may occur. Soft tissue changes become evident if horizontal and vertical extension values are compared before and after treatment (Fig. 9 and 10). The alteration of the soft tissue mass is in part postural, reflecting a change in the manner of lip closure and in part, the result of growth. Further investigations are needed to determine if altering dentoskeletal structures or myofunctional therapy can inherently change the soft tissue mass of the face (non-postural alteration).

In an orthodontic case, esthetics is closely related to stability. Rarely should facial esthetics be achieved at the expense of denture stability. Stability and esthetics need not be separate objectives, for those same muscular imbalances that may operate to produce denture instability may also be responsible for disharmony in facial contour.

The present study is basically static in nature. Future functional investigations are needed to relate variation in soft tissue mass with the muscle activity of the orbicularis oris complex.

Fig. 9 Integumental extension changes incident to orthodontic treatment, A) pretreatment, B) posttreatment.

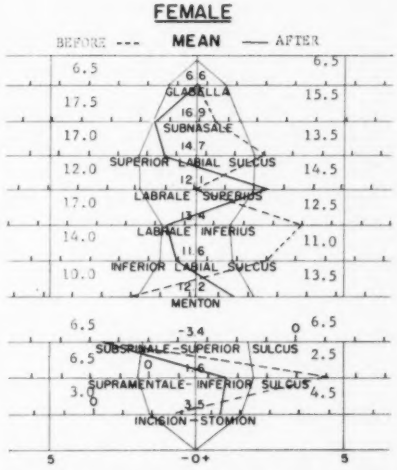


Fig. 10 Integumental extension changes of patient shown in Fig. 9. Dotted line — pretreatment, solid line — posttreatment.

Summary

1. Utilizing the oriented lateral headplate, a method of measuring integumental (vertical and horizontal) extension was presented.

2. Integumental extension standards based on artist-chosen samples were established for adolescent and young adult groups.

3. Malocclusions exhibited considerable variation in integumental extension from the means of the standards. If accumulative variation were measured, deviations from the average increased in value.

4. Sex differences were noted in integumental extension. Areas inferior to the nose in the male, generally, had greater horizontal extension of soft tissue.

5. Maturational changes in the integumental profile from adolescence to the young adult were considered. Significant differences were demonstrated in: lower facial, mandibular, interlabial, superior labial, inferior labial, and supramental inclinations. The only contour angle to show a significant difference was total facial contour which tended to flatten with age.

6. Increasing evidence suggests that an awareness of variation in the soft tissue mass should become an integral part of orthodontic case analysis.

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Tissue Rearrangement During Retention Of Orthodontically Rotated Teeth*

KAARE REITAN, M.S.D., Ph.D.,
Oslo, Norway

The mechanical procedure of rotating malposed teeth has seldom been considered a problem in orthodontics. On the other hand, it is well known that the rotated tooth frequently shows a tendency to move back toward its original position after removal of the appliances. This occurs especially in cases where the respective tooth has been rotated rapidly and through a considerable number of degrees. In some textbooks overrotation has been recommended as a measure against these secondary changes in tooth position.

Other methods have been suggested for stabilization of rotated teeth. Hence, Skogsborg (1927) advocated surgical transection of fibrous and bone structures in the septal area on both sides of the root, after rotation, in order to prevent relapse of the tooth moved. Recently Hallett (1956) discussed the results obtained after immediate torsion of twenty-three teeth, the so-called "redressement forcé"; the teeth thus rotated had been retained by fixed splints. The descriptions of these two methods tend to stress that there are problems connected with rotation of teeth, but that these problems are related chiefly to the retention period. The present investigation is based on animal experiments and deals with some histologic observations made in the supporting structures of orthodontically rotated teeth.

Up to the present few histologic experiments on rotation have been reported. One series was performed twenty years ago (Skillen & Reitan 1940), the findings of which are partly discussed in this study. In addition, a new series will be described, also including experimental teeth that were retained after rotation. Except one dog, two and a half years old, the experimental animals were around one year old. The new series comprises sixteen experimental teeth, six of which represent experiments on retention.

ROTATION OF TEETH

Various factors are involved in the movement of rotation. Of these the anatomical and mechanical factors should be considered here. The anatomical factor is primarily related to the position of the tooth, its form and size. Except the upper central incisor and to some extent the first and second lower premolars in man, most roots, seen in cross section, have an oval form. In the present series the upper second incisor in the dog was selected as the experimental tooth, the first and third incisors serving as control. In cross section the second incisor of the dog has an oval contour, Fig. 1. Because of this

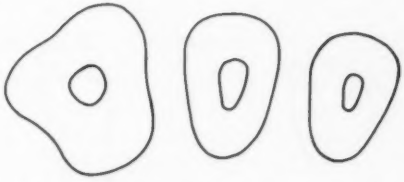

Fig. 1 Cross sections of the first, second, and third upper incisors of the dog.

* From the Norwegian Institute of Dental Research, Oslo.

form a parallel movement between the root surface and the inner alveolar bone surface takes place chiefly on the buccal and lingual sides of the root. Another anatomical detail to be mentioned is the arrangement of the periodontal fibers.[6] It is well known that the major group of the periodontal fiber bundles runs from the root surface to the inner alveolar surface. The free gingival fibers, however, are attached in the gingival soft tissues and the periosteum. As shown later, this variation in the attachment of the fibers plays an important part especially during the retention period.

The mechanical factor primarily influences the degree of rotation. For the sake of clarity, the root may be divided into two halves, one lingual and one labial. It is found that the mechanics of the appliance will determine which portion of the root will be moved the most. The appliances used in the experiments are seen in Figure 2. Two of the experimental teeth were ligated directly to a 0.7 mm. labial arch. By this type of appliance some movement was obtained, mainly of the lingual portion. Traction exerted by one spring would increase the movement of the lingual portion, a method applied in two cases. Still more rotation was obtained when this force was counteracted by a spur resting on the labial surface of the tooth, Fig. 2B.

Eleven teeth were moved by springs exerting traction in opposite directions,

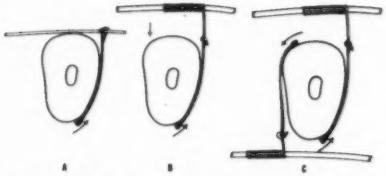

Fig. 2 Methods applied for rotation. Upper arrow, B, indicates spur counteracting traction by spring.

by which a considerable rotation could be obtained, Fig. 2C. Each of these springs exerted forces around 30 g. The degree of rotation obtained varied between fifty and seventy degrees. By grinding occlusal surfaces, the tooth to be rotated was kept out of occlusion as long as the experiment lasted. Figure 3 represents the average degree of rotation. The time periods required for this movement varied between eight to twelve weeks in the younger animals. Slightly more time was required for rotation of the teeth in the older animal, an observation which is well

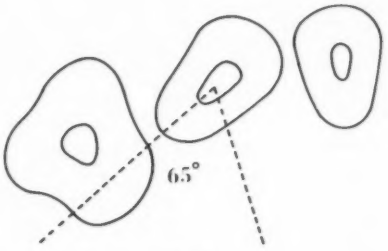

Fig.3

known from other experiments.

The areas to be examined may be divided into marginal, middle and apical regions, Fig. 4. In the free gingival fiber group of the marginal region, a marked displacement and stretching of fibrous structures was observed in all cases. Because the free gingival fibers are continuous with the whole fiber system of this area, stretching will cause displacement of fibrous structure at some distance from the rotated tooth, Fig. 5. This seemed to be caused primarily by the fiber group attached to the lingual or labial surfaces of the root, Fig. 6. It was even found that tension had been exerted on the epithelial processes, which were inclined as a result of traction by subjacent fibrous structures.

In the middle region, usually bone

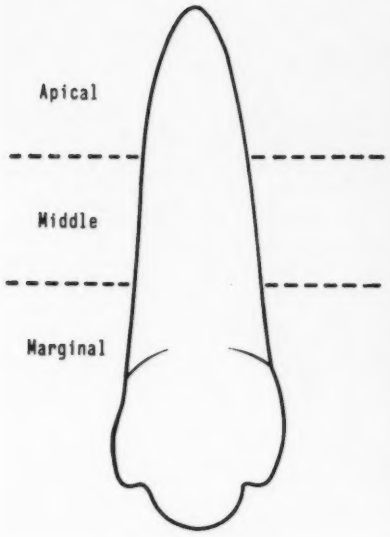

Fig. 4

Fig. 6 Cross section of the marginal region, well-spaced teeth. A, fiber bundles adjacent to the rotated tooth, arranged obliquely. B, normal arrangement of periodontal fibers adjacent to the control tooth, C. D, undistinct layer between stretched and relaxed fiber bundles.

resorption was observed in two pressure areas, while there was stretching of periodontal fibers and bone formation in two corresponding tension areas, Fig. 7. Great variations existed in the degree of tissue response on the pressure sides. In a few experiments of short duration compressed cell-free fiber bundles were found in one pressure area and direct bone resorption in the other. Frequently direct bone resorption was observed in areas where the root was moved parallel to the bone surface or where the pressure was moderated because the tooth moved contacted the proximal tooth. A typical direct bone resorption of the lingual area is seen in Fig. 8. Indirect resorption had taken place more frequently in the labial than in the lingual pressure areas. Because an indirect resorption process will last for two to three weeks,[5] undermining of compressed areas was completed in all experiments of longer duration. Shallow root resorptions were observed in some cases together with an extensive undermining of bone tissue. Two teeth, not included in this series and rotated nearly 90°, exhibited corners that were flattened by resorption during tooth movement, Fig. 9. Such aftereffects of an indirect bone resorption can hardly be avoided and represent a typical reaction follow-

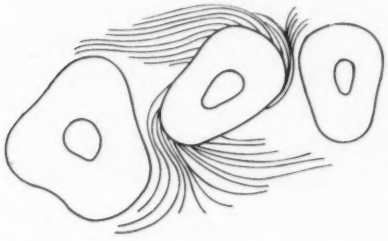

Fig. 5 The arrangement of free gingival fibers following rotation of teeth.

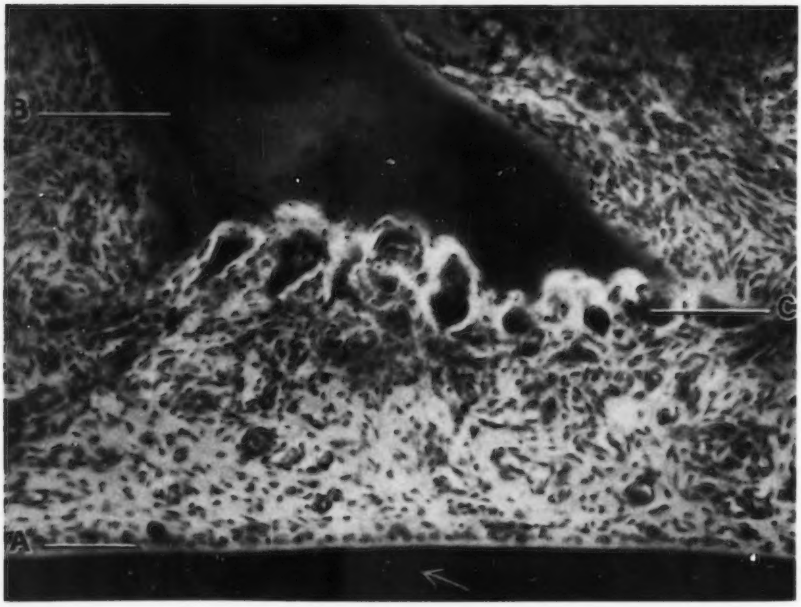

Fig. 7—Above. Section of the middle region. A, resting lines between old and newly formed bone, B. C, thin bone layer between control tooth and rotated tooth.

Fig. 8—Below. Cross section of a pressure area. A, thin cementum line along the root surface; the tooth moved as indicated by arrow. B, protruding bone spicule under direct resorption by large osteoclasts, C.

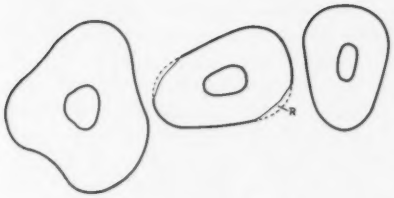

Fig. 9 R, amount of root substance removed by resorption following extensive rotation.

ing an extensive rotation of teeth. In some instances resorbed areas of the root were already repaired by cellular cementum.

The changes taking place on the tension sides were greatly influenced by the traction exerted on fiber bundles. A demarcation or resting line was observed between old and new bone layers. New bundle bone and osteoid tissue were found arranged in tongue-like spicules along stretched fibers, Fig. 10. Hence opposition of new bone is stimulated by the traction exerted by fiber bundles.[3,4] This traction will also stimulate formation of cellular cementum along the root surface. In some cases a marked increase in the thickness of the cementum layer was found on the tension side, Fig. 10, while very little cementum had been deposited on the pressure side, Fig. 8.

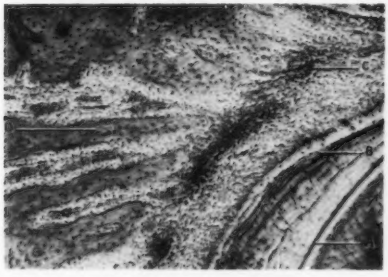

Fig. 10 Tension side, middle region of upper second incisor in older animal. A, line indicating thickness of cementum layer; B, demarcation line between old cementum and rapidly formed new cementum layer; C, zone with proliferating cells; D, new bone spicules formed as a result of tooth movement.

In the apical region the supporting fibers were arranged obliquely. A moderate increase of new bone layers was observed in certain areas of the inner bone wall.

Since rotation causes extensive changes in the alveolar bone, with elongation of fiber bundles in the periodontal membrane as well as stretching and displacement of the free gingival fibers, it is obvious that the rotated tooth must be retained while rearrangement of these structures takes place. In experiments on retention one should be able to observe the length of time required for a rearrangement of the structures involved.

Retention after rotation

The retention appliance consisted of bands cemented on the first and second upper incisors. The rotated tooth was maintained in position by two short pieces of wire, one soldered to the lingual sides and one to the labial sides of the bands. The end of the labial section rested on the labial surface of the third incisor. In cases where the tooth had been rotated in the opposite direction, the end of the lingual section rested on the lingual surface of the third incisor. An examination of the supporting structures of retained teeth may be applied to the same areas as mentioned previously, i.e. the marginal, middle and apical regions. Two kinds of tissues are of special interest, the fiber bundles of the periodontal membrane and the newly formed bone tissue.

Fibrous tissue. As seen from Table I six teeth were retained for periods varying from 15 to 232 days. Rearrangement of fibrous tissue means that the periodontal fiber bundles are again running more or less perpendicular from the root surface, as seen in the

Rearrangement of Fibrous Tissue

Tooth	Retention	Marginal Region	Middle Region	Apical Region
+2	15 days			
2+	28 days		++	++
+2	57 days	+	++	++
2+	83 days	+	++	+++
+2	147 days	+	+++	+++
2+	232 days	+	+++	+++

Table I + indicates partly, ++ fairly well, and +++ completely rearranged fibrous tissue after retention.

supporting structures of the control teeth. In Table I the marginal region comprises the areas of the gingival free and transversal fibers. It was found that no rearrangement of fibrous structures had taken place in the marginal region after retention periods of 15 and 28 days. The periodontal fibers were running obliquely, partly parallel to the root surface. In the other cases some rearrangement was observed, chiefly on the mesial and distal sides of the root. It was noted that the fiber bundles attached to the labial and lingual sides of the root were still under tension.

In areas where the teeth were well spaced, the transversal fiber group was arranged in two layers, one running obliquely from the experimental tooth, the other perpendicular from the surface of the control tooth. A similar arrangement is seen in Fig. 6. In other areas where the tooth position was narrow, silver impregnation staining would disclose that the transversal fiber bundles were elongated and running obliquely from the rotated tooth to the control tooth. In areas close to the bone crest the transversal fibers gradually assumed a more normal arrangement. It is of interest to note that the free fiber bundles of the teeth, retained for 147 and 232 days, still remained stretched in accordance with the previous movement of rotation. This especially applies to the fiber bundles attached to the labial and lingual surfaces of the root, Fig. 11.

In the middle region of the root (Table I) the periodontal fibers were still arranged obliquely after a retention period of 15 days. After 28 days the fiber bundles were fairly well rearranged. This applies to the retention periods of 57 and 83 days as well. Complete rearrangement was found after periods of 147 and 232 days.

In the apical region a rearrangement similar to that observed in the middle region had taken place. Figure 12 shows an area from the labial side of the root retained for 147 days. The orientation of these periodontal fibers can hardly be distinguished from that of a control area.

Bone Tissue

The observations made of bone changes are listed in Table II. In all regions very little rearrangement was observed after a retention period of 15 days, with partial rearrangement after 28 days; a more advanced bone reorganization had occurred in the other cases. It was seen in the first section of this study that new bone was formed along stretched fiber bundles. This tongue-like bone formation was observed in the experiments on retention after periods of 15 days. After retention for 28 days new bone had been

Rearrangement of Bone Tissue

Tooth	Retention	Marginal Region	Middle Region	Apical Region
+2	15 days			
2+	28 days		+	+
+2	57 days	+	++	++
2+	83 days	++	++	++
+2	147 days	++	++	+++
2+	232 days	++	+++	+++

Table II + indicates partly, ++ fairly well, and +++ completely rearranged bone tissue after retention.

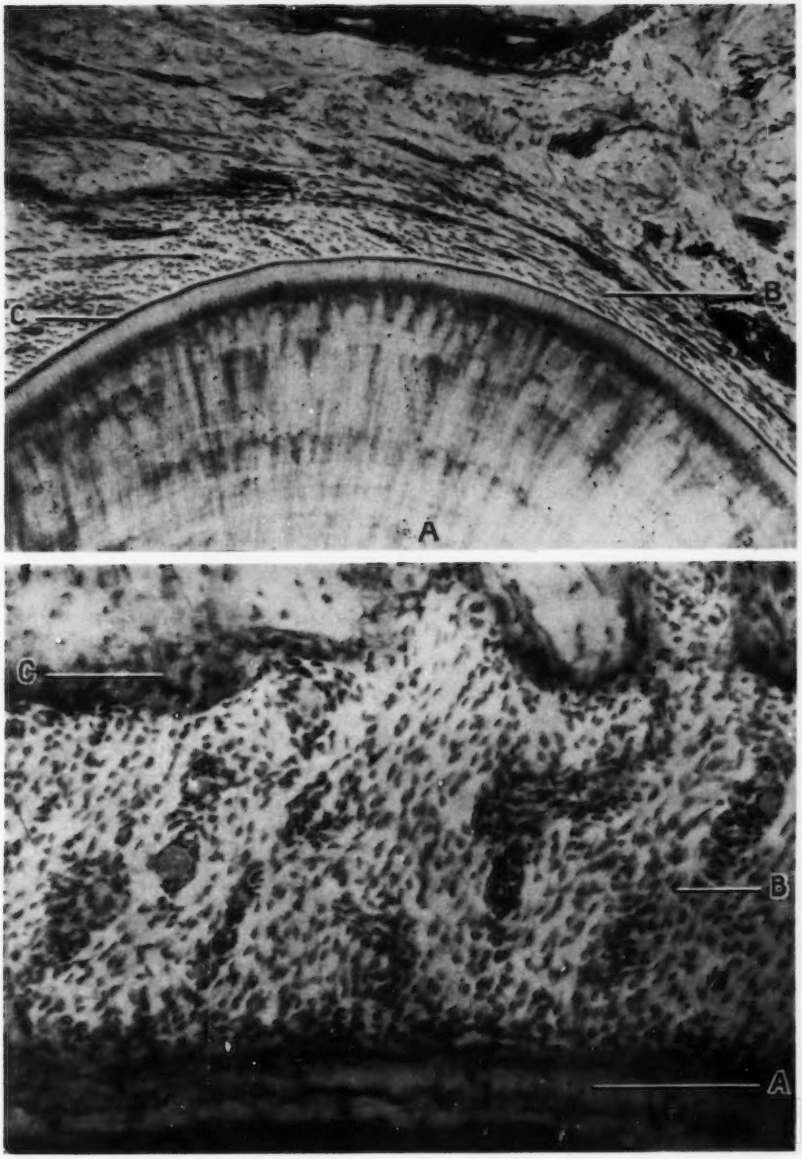

Fig. 11 — Above. Marginal region, cross section of rotated tooth, A, retained for 232 days; B, elongated and stretched fiber bundles; C, thin cementum layer along the root surface.

Fig. 12—Below. Apical region, cross section of tooth retained for 147 days; A, cementum layer of root surface; B, rearranged fiber bundles of periodontal membrane; C, rearranged alveolar bone tissue.

Fig. 13 A, illustrating how bone spicules are formed along stretched fiber bundles; B, rearrangement of bone tissue following retention of the tooth moved.

added between these first bone spicules. Figure 10 shows an area of the tension side in one of the non-retained cases. In a corresponding area of the tooth retained for 57 days, new bone had filled out the spaces between these spicules. The transformation of bone structures may be illustrated as seen in Fig. 13. After retention periods of 147 and 232 days a still more complete reorganization of bone tissue had taken place, Fig. 12.

Discussion

In a discussion of the present findings one may question to what extent the supporting structures of animals can be compared with human tissues. It appears that the arrangement of the supporting structures in man and the dog is fairly similar. The changes taking place in the alveolar bone are also quite similar. The periodontal fiber bundles, however, are coarser in the dog than in man and the bone tissue in the dog is frequently denser. One should also remember that in practice rotated teeth are usually moved to a position of greater mechanical advantage. The opposite is frequently the case in experimental tooth movement. These reservations must be taken into consideration when experiments on rotation are evaluated.

It has been shown in the series of retained cases that the arrangement of the structures in the gingival fiber group is different from that seen in other areas. The persistence of stretching and displacement of fiber bundles in the marginal region indicates that complete rearrangement of the supporting structures requires a longer period of retention than 232 days.

Why free gingival fibers remain in a stretched position may be explained by the fact that they are attached to a movable fibrous system which, to some extent, may be displaced even at some distance from the tooth moved. In addition, the supra-alveolar structures contain elastic fibers which may yield to traction during rotation. The result of this will be a tissue that will remain stretched during the retention period. Forces leading to contraction of these fiber bundles will enter into action at the moment the tooth is released, by which relapse of the tooth moved may occur.

On the other hand, the periodontal fibers, running from the root surface to the bone surface will be fairly well rearranged after a retention period of twenty-eight days. It is therefore not likely that relapse of a retained tooth is caused by contraction of principal fibers, but primarily by a persisting displacement of supra-alveolar structures in the marginal region.

In his articles on this problem, Skogsborg (1932) advocated transection of fibers and bone structures in the septal areas of the tooth moved. According to the present findings this is certainly necessary if the rotated tooth is not retained at all. Because contraction of the gingival fibers may be strong enough to cause resorption of new bone layers adjacent to the rotated tooth even after a retention period, it would seem advisable in extreme cases to transect stretched fibers in the marginal region. Surgical transection of bone structures would hardly be necessary following a retention period.

The easiest way, however, to solve the problem of rotating teeth would be to correct the tooth position as early as possible, preferably before the apical portion of the root is developed. New periodontal fibers would then be formed after rotation and thus prevent relapse of the tooth moved.

Summary

Experiments on rotation and retention of rotated teeth in young dogs reveal that some of the gingival fiber bundles will remain displaced and stretched even after a retention period of 232 days. Periodontal fibers running from the root to the bone surface will be rearranged within a retention period of 28 days. Relapse of the rotated tooth after retention seems to be caused primarily by a contraction of displaced gingival fibers and other supra-alveolar structures. According to the e findings overrotation of teeth would seem advisable in order to ensure a correct tooth position after the retention period. It would also be an advantage to transect stretched fibers around the tooth moved. Early correction of a rotated tooth position would prevent relapse of the tooth moved because new fiber bundles, formed in the apical region, would assist in retaining the rotated teeth.

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Indirect Band Technic

JOHN T. LINDQUIST, D.D.S.
Indianapolis, Indiana

Until the discovery of Magic-X, orthodontists will have to continue their band making efforts. Magic-X is that perfect adhesive which will enable brackets and tubes to be cemented directly to the teeth. Perhaps this revolutionary material will be discovered soon — perhaps never. In the meantime, any improvements in band making procedures should be welcomed by the profession. This paper will present an original indirect band technic which has proven itself in several years of clinical practice. It overcomes many of the objections to previous methods and, in addition, it is actually an indirect appliance construction method rather than a band technic alone. It has been designed for indirect construction of a complete edgewise arch appliance; however, any multiple banding appliance can be adapted to this technic.

It has not seemed feasible to most orthodontists to make bands by an indirect method. The quality and fit are believed to be lacking. This may have been the case with some previous methods, but it is no longer true. Orthodontics is in about the same stage now that crown and bridge work was about ten years ago. Until the advent of a good hydrocolloid technique most dentists had the same doubts about indirect inlay work that we orthodontists have about indirect appliance construction. Prior to hydrocolloid few men would cast an inlay without trying the wax pattern in the mouth — even if a so-called indirect method was used. Today the completely indirect hydrocolloid method is very successful and has gained widespread acceptance. This comparison is being drawn merely to promote unbiased thinking.

Band construction by any direct method, including the use of preformed bands and contoured band strips, has always been a time consuming and fatiguing procedure. The mental strain and fatigue of the orthodontist can only be matched by the discomfort of the patient. Most of this discomfort can be eliminated by the procedures to be explained. With the technic to be presented, it is also possible to eliminate the work and discomfort involved in taking individual impressions of each tooth to be banded. Most indirect band technics require individual tooth impressions, usually taken with copper bands or aluminum shells. A single upper and lower impression is all that is now required. From these impressions extremely hard metallic type dies are made of each tooth. After bands have been constructed from these dies all brackets and tubes can be accurately positioned. Initial archwires and a face bow headgear can also be constructed— all from a single impression of each arch. Competent technicians can be trained to do this work, leaving valuable time for the orthodontist to better care for his patients. Added to these obvious advantages is the possibility of constructing a superior appliance, for band adaptation and bracket and tube placement can be definitely better than with direct methods.

Appliance construction by this indirect method is a three stage procedure. Separation, impressions, check

Read before the Edward H. Angle Society of Orthodontia, Washington, D.C., 1957.

fitting and cementation are all that is required. A complete appliance can be seated at one appointment after the teeth have been separated and impressions taken. Chair time can be reduced by more than one-half.

The development of this technic was made possible by the introduction of two new materials. The first of these is rubber base impression material. With it an impression can be taken that will extend under the gingival tissues slightly and increase the length of the clinical crown on the model. This material also makes possible the use of some superior die materials. The second new material is a die material that is very accurate and possesses extreme surface hardness and strength. Plastic steel was adapted by the author for use in dentistry with the rubber base impression materials. It is composed of 80% finely powdered steel particles and 20% plastic. The surface hardness is much better clinically than copper plate or low fusing metal dies. Hydro-cal or stone dies exhibit excessive surface wear and are generally unsatisfactory for band construction.

With an impression material that is capable of reproducing the tooth surface slightly under the gingival margin and a superior die material the following technic was evolved over the last three years. In its final form, the die positioning portion was patterned after a technic that is used in crown and bridge work. The dies can be re-assembled to the exact form of the original malocclusion model. Accuracy is so positive that fixed bridges can be constructed by this method.

A detailed step by step procedure will now be given. This will be followed by a discussion of the advantages and disadvantages of adapting this method to a busy orthodontic practice. Finally, the advantages of chrome steel and chrome nickel alloys will be stated in reference to use with the indirect appliance construction technic.

Separation

Adequate separation is an absolute necessity for successful use of this technic. This is essential, however, for good band construction by either direct or indirect methods. Separation must be obtained between each tooth in the mouth. This should be of such degree that all bands can be cemented at one time without binding, or forcing the teeth apart during cementation. The amount will depend upon the thickness of band material used and the closeness of band adaptation. When this amount of separation is obtained, the impression material will flow between the contact areas and accurately reproduce the mesial and distal surfaces of the teeth involved. A septum of this tough rubber material will separate all teeth in the impression after it is removed from the patient's mouth. The importance of this will also be realized when the dies are reassembled to the form of the original model.

Separation of this degree can be obtained with a minimum of discomfort by using some of the so called "physiologic" methods. Kesling separating springs are excellent for use on posterior teeth. Brass wire can also be used on cases where separation is not difficult to obtain. If teeth are to be extracted, this should be done approximately one week before separation is placed. Springs or wires should be placed three or four days before impressions are to be taken. In extremely difficult cases these should be replaced or tightened and allowed to act longer. Anterior teeth can be separated with Maxian elastic separators which are usually placed one day before impressions are taken. Many patients can be instructed to place these at home, thereby eliminating an extra visit to the

orthodontist. If left longer than one or two days, these elastic separators can be irritating to the gingival tissues. On less difficult cases brass wire can be placed on the anterior teeth at the same appointment when the springs are seated. By using the "physiologic" methods, i.e., springs and elastic separators, much of the discomfort of separation can be eliminated and extra appointments avoided.

Impression Technic

All separating springs, wires, or elastics are removed and the teeth thoroughly cleaned. A rubber cup of the B.S. type is used with pumice to clean the tooth crowns. This style cup will flare out and extend below the gingival margin. It is very important that this area be clean. Scalers should be used if calculus is present. The distal surfaces of the lower second molars should be packed with a string or wisp of cotton saturated with a 20% solution of zinc chloride if tissue covers these areas and it is desired to band them. This is placed at the beginning of the appointment. By the time the rubber base impression is ready to be taken the tissue will be retracted, thereby eliminating a waiting period for this action. It is usually unnecessary to pack any other areas since the impression material will flow slightly under the gingival margins if these areas are properly cleaned.

A compound impression of each arch is taken. This acts as a tray for the rubber base material. The compound impressions are jiggled when first seated to enlarge the space for the teeth; by moving or jiggling the impressions, enough room for the secondary impression can be created. This eliminates the need for trimming or removing material after the compound is taken from the mouth. Additional space can be created if needed by working the end of a mirror handle in the soft compound immediately upon removal from the mouth. One of the fundamental principles of using rubber base impressions is to have a close adapting tray which minimizes the thickness of the impression material. The compound impression tray also provides a peripheral seal all around the impression which may help to force the impression material below the gingival margins. For these reasons the use of the compound tray is recommended.

To insure proper working consistency of the compound it is necessary to have water temperature at the manufacturer's recommendation or slightly higher. An automatic saucepan, as shown in Figure 1, is ideal for this purpose. It can be calibrated to the power temperature by using a thermometer and marking the dial. When once calibrated, it will thermostatically keep the water within a three degree variation. The compound can be heated before the patient arrives and will stay at the proper working consistency for as long as desired. Figure 1 also shows the loaded tray. An average size tray will require 1½ cakes of compound. Upon removal from the mouth the impression

Fig. 1

is dried with air. The use of an adhesive is recommended. A thin coat of adhesive will prevent the rubber base material from pulling away from the compound. This is necessary with some rubber base materials. If no difficulty of this type is encountered, the adhesive is unnecessary.

A heavy-bodied type rubber base material such as Kerr's Heavy Bodied Permlastic is used. Three to four inches each of the base and accelerator tubes are squeezed onto the mixing pad. It is thoroughly mixed as quickly as possible and loaded into the tray. A cement spatula is used to mix the material. Seat with firm, but not excessive pressure. Experience will provide the right balance which will force the material under the gingival areas and still keep the compound from touching the teeth as little as possible. The tray is held in place by the assistant or hygienist, leaving the orthodontist free at this point to care for another patient. It is imperative that the material be allowed to set in the mouth for at least seven minutes, regardless of the manufacturer's recommendations. It is extremely important that the patient does not close on the tray during the curing period. A saliva ejector is recommended to eliminate the need for swallowing. If large areas of compound show on the finished impression, it indicates that biting of the tray has taken place. The impression is removed from the mouth with a quick motion thereby preventing distortion. Separation is replaced at the end of this appointment. Figure 2, taken of a completed impression, illustrates nicely the septum of rubber between each tooth. A close-up of another impression as seen in Figure 3 was taken to show the feather edges of material that extend beneath the gingival margins.

Die Construction

Recent research indicates that rubber base impressions should be poured within an hour to retain their accuracy. Formerly it was believed that the completed impressions would remain dimensionally stable for long periods.

Completed impressions are boxed with a weather stripping compound. They should be built up with strips of material to a height of thirty mm. as measured from the cusp tips. This will insure dies of adequate length.

The impression is then poured in

Fig. 2 Above, Fig. 3 Below.

Fig. 4

Devcon Plastic Steel. The resulting dies are composed of 80% steel and 20% plastic. Devcon consists of a putty-type material to which a liquid hardener is added and the two thoroughly mixed. They are combined at a ratio of one tablespoon of putty to a teaspoon of liquid. Two tablespoons of putty are sufficient for the average impression. When mixed, the material has the consistency of a thick syrup. To insure bubble free models, a thin layer of the material is painted into the crowns of the teeth with a fine brush. Figure 4 shows the material being painted into the crown portions. Boxing material was removed to make the photograph possible. After a thin layer is present, the remaining material can be poured into the impression. A poured impression is illustrated in Figure 5. Plastic steel will harden in four or five hours. After this time, or preferably overnight, the model can be separated. The compound is re-heated to the original working temperature and removed. The rubber base material will peel off easily, unless the compound has been overheated.

At this stage we have a plastic steel model of each arch. This will be cracked apart to form individual dies of each tooth. The dies are then trimmed at the cervical region to extend the crown portion three to five millimeters below the original gingival line. Individual dies are held in a vise and bands constructed. Upon completion of banding, the dies are re-assembled to the original model. Brackets and tubes are placed where needed and initial archwires and face-bow headgear constructed, if desired. This synopsis was given to clarify the procedure before describing each step in detail.

Fig. 5 Above. Fig. 6 Center. Fig. 7 Below.

Tapered sides are formed on the base of the plastic steel model with an arbor band on a lathe. Figures 6 and 7 show the trimmed model. The base is lubricated with vaseline, or other separating material. The model base is inserted into a mix of hydro-cal to a depth of approximately $\frac{2}{3}$ of the total model height. The stone core or key that is thus formed is illustrated in Figures 8 and 9. Upon removal from the core, the plastic steel model is separated into dies in the following manner. A ribbon saw blade is passed between the contact areas and a cut made to a depth of approximately three millimeters. These cuts are extended on the labial and lingual of the model with a separating disc or diamond disc. They are shallow cuts not more than two millimeters in depth. The model is not cut apart with the disc or saw; we are merely establishing cleavage lines. These cleavage lines are seen in Figure 10. A cutting plier is inserted into the shal-

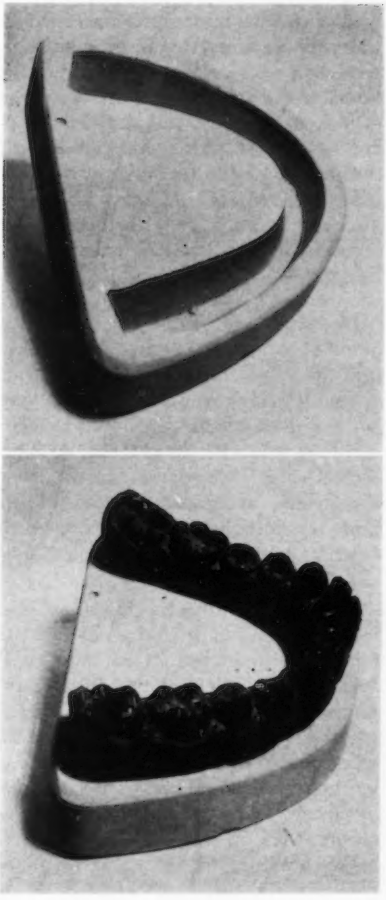

Fig. 8 Above. Fig. 9 Below.

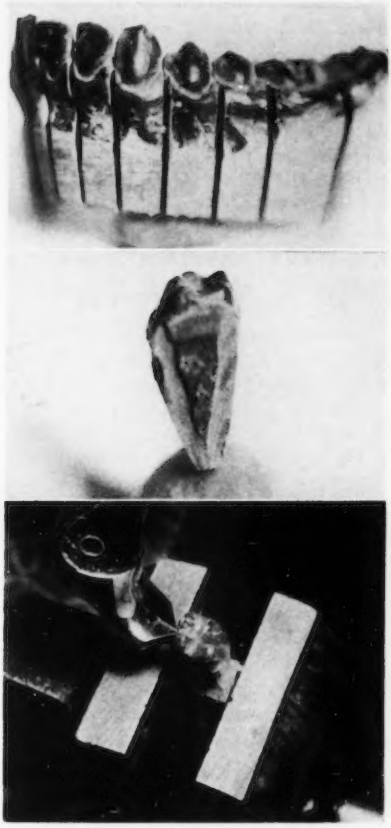

Fig. 10 Above. Fig. 11 Center. Fig. 12 Below.

low cuts and the dies are cracked apart. It is vital to later re-assembly that the dies be cracked apart and not cut apart. A cross section of a die showing the cleavage lines and cracked surface is shown in Figure 11.

A knowledge of dental anatomy is essential for proper trimming of the cervical portion of the dies. A steel vulcanite bur is used to trim this portion of the die. The crown is extended gingivally three or four millimeters below the impression line. It is not difficult to accurately reproduce this portion of the tooth; the contours of the crown are followed and extended into this area. Some type of dust collection is needed while grinding the plastic steel. A suction apparatus designed for this purpose would be ideal. Small steps or parallel lines are cut on the labial and lingual of the die base to enable it to be held in a vise. The dies can be re-assembled into the stone core at any time and the original plastic steel model will be reproduced.

Band Construction

Bands are constructed of chrome alloys for many reasons; however, gold can be used. Both straight band material and contoured blanks are used. Peak pliers are used to form the bands as they are capable of stretching the band material around the contours of the teeth and make superior bands. All band strips except lower anteriors are formed into a contoured convex blank. The ends are welded together and the contoured blank is slipped over the die. The labial or buccal surfaces are adapted to the die with a band pusher before the band forming pliers are used. Figure 12 shows the completed pinch with the pliers. Note how carefully the band is adapted to the die at this stage. Upon removal from the die, the band is welded along the seam. On bell shaped teeth the welding spots are moved a millimeter away from the seam. The excess material is removed and the gingival margins are contoured or cut to the desired shape. The band is returned to the die and the "tail" is folded over. It is again removed and the "tail" welded to the lingual of the band. Figure 13 is a view of a completed molar band. Anterior bands require that the pliers be modified to a convex instead of a concave beak. Howlett or Angle band-forming pliers may also be used. Brackets are pre-welded to all band strips except cuspids and molars. Brackets are angulated in most cases to produce better control of axial inclinations; however, this is beyond the scope of this paper. It is felt that more accurate bracket placement can be accomplished by attaching the molar tubes and brackets and cuspid brackets after the bands have been formed and re-assembled into the original model.

Die Re-assembly

At many times during the band formation process the dies are re-assembled into the stone core. Bracket height can be easily checked. Occlusal interferences with band placement and bracket and tube placement can be checked and corrected if needed. Re-assembly is completely accurate; in fact fixed bridges can be made and assembled on models such as these.

Molar tubes can be tack welded to the bands by the technician as well as molar and cuspid brackets. It is possible for the orthodontist to angulate these attachments if desired without removing them from the bands. If they are incorrectly located, they can be twisted off and relocated in correct positions by the technician. This is a tremendous advantage and is possible only by using chrome alloys. Chrome-nickel alloys make possible the soldering of tubes to bands after they have been tack welded in proper position. Tube placement

by this tack welding and soldering operation is usually more accurate than using tubes with welding flanges.

It is easy to visualize how the complete appliance can be constructed by this method. Band accuracy is such that almost every band will fit the tooth in the same relationship that it does on the re-assembled model. Initial archwires are formed on these models after all bands and attachments are completed. Auxiliary .045 tubes can be soldered to the upper first molar bands and a complete face-bow headgear assembled from this same model. In time we may be able to construct all arch wires needed during treatment before the first band is cemented. Laboratory time will be increased, but chair time drastically decreased. It is possible that a whole new era in orthodontics could be introduced by widespread adoption of indirect procedures. Figures 14 and 15 are photographs of a completed edgewise appliance on the re-assembled model.

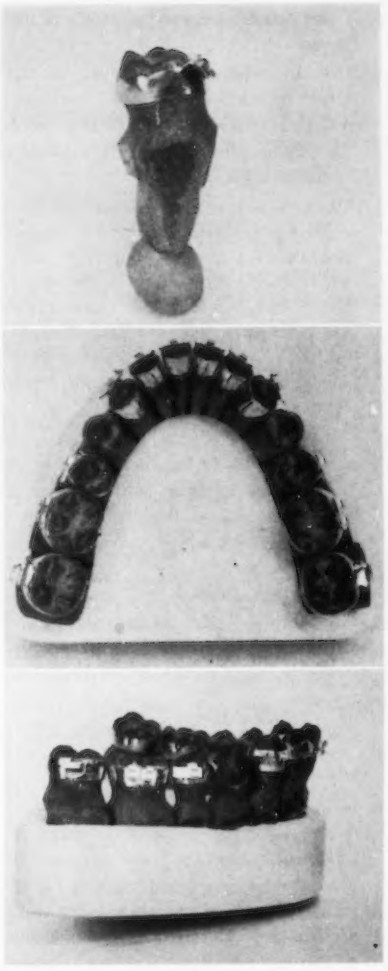

Fig. 13 Above. Fig. 14 Center. Fig. 15 Below.

Band Fitting and Cementation

Very little fitting is required. A Hollenback pneumatic condenser is used to seat the bands. These bands fit in every sense of the word. If properly constructed on the dies, there is no "rock or roll" to them. They go to one position and only one. The cervical fit is of prime importance. Bitewing x-rays will readily convince one of the superiority of the bands in this respect. If a steel band is too large, it is a simple matter to cut it in two on the lingual, overlap the required amount, and weld back together. The contour and fit is not destroyed by this process. If a band is too small, it may be stretched slightly with band stretchers to the desired size. This is necessary only when the dies are incorrectly trimmed, which seldom happens. Bands are cemented a quadrant at a time. With this outline of the procedure completed, a brief outline of the advantages of chrome alloys will be given.

Advantages of Chrome Alloy

1. Stronger bands — better edge strength.
2. Better fit — retains contour better.

3. Takes and retains mirror bright finish.
4. Stretches over a die or tooth during band formation without breaking, and thus gives a better fitting band. The Peak pliers utilize this quality to the utmost.
5. Allows brackets and tubes to be tack welded for a trial fitting or inspecspection. If they are not right they can be twisted off and re-positioned. This is a big advantage since auxiliary personnel place the attachments, but the orthodontist has a final check before they are completely welded.
6. It is much easier to train auxiliary personnel in welding techniques than in soldering. Welding with the newer welders is almost foolproof. Soldering, as we all know, takes quite a little practice.

In closing, a summary will be given of the advantages and disadvantages of adapting this indirect appliance construction method to a busy orthodontic practice.

Advantages and Disadvantages

Advantages:

1. It is much kinder to the patient. Think how much easier it must be from the patient's point of view to have a set of impressions taken, a little band fitting, and then have their appliances cemented. Contrast this to the tearing of the gingival attachment and malleting that are inevitable with direct methods. This consideration of our patients is in my opinion the number one advantage of this method.
2. It is much easier on the orthodontist. Much of the fatigue, both mental and physical, is taken from band construction.
3. It takes less time. The exact amount of time will depend on the speed of the orthodontist but this method should reduce chair time by more than fifty per cent.
4. It results in a superior appliance. Both the bands and the accuracy of attachments are improved.
5. It is tailor made for the use of chrome alloy. The advantages of this have been explained.

Disadvantages

1. It requires the services of a trained technician, either male or female. Every busy practice should be able to absorb a full time technician, not of course for band making alone, but for the numerous other phases of practice that someone else can be trained to do as well as we would do it ourselves.
2. It involves an extra step of chair time. The time it takes for the impressions is, however, quickly saved during the later stages.
3. The adoption of this method requires a change in the office routine. Progress however stops for no one. It is economically unfeasible to both patient and orthodontist to have the orthodontist do things which auxiliary personnel can be trained to do.

3311 N. Meridian St.

Case Report*

A. J. Wildman, D.D.S., M.S.D.

Eugene, Oregon

This case was selected for presentation because the anchorage problem involved presented an interesting challenge. I felt that achievement of an excellent face and an acceptable occlusion might be a difficult task.

History

The patient was eleven years old when she presented for treatment. Her medical history included the usual childhood diseases but no serious illness. There was no history of adverse habit patterns.

Diagnosis

When the skeletal pattern was compared with the Downs' analysis, it appeared excellent. It may be seen in Table 1 that all measurements for the skeletal pattern were well within the normal range. Measurements for the Downs' analysis involving tooth position indicated a slightly protrusive lower incisor and a very protrusive upper incisor.

Analysis of the models, which are shown in Figure 1, reveals that this patient had a Class I malocclusion. There was 6 mm. crowding in the upper arch and 9 mm. crowding in the lower arch. An overbite problem existed and there was considerable overjet. The profile, seen in Figure 2, was very poor. It was possible for the patient to close her lips completely only with considerable difficulty.

Etiology

Discrepancy between tooth size and basal arch length seemed to be the basic problem in this case. No evidence of perverted swallowing could be detected. No definite familial patterns could be established.

Treatment

It was obvious that this case presented an anchorage problem. It seemed that if care were not taken, enough anchorage might be lost retracting the cuspids to preclude satisfactory reduction of the existing protrusion. The treatment plan was devised to protect anchorage to the utmost. The four first bicuspid teeth were removed and an edgewise appliance was placed. The remaining teeth with the exception of the third molars were banded. The upper second molar bands carried .045 buccal tubes as well as the edgewise tubes. A Kloehn-type headgear was constructed. Stops were placed on the headgear arch in a position which allowed the posterior of the arch to protrude from the buccal tubes to provide an extension for accommodating elastics.

Round arches were used while the cuspids were being retracted. Elastics were worn from the end of the headgear arch to sliding hooks acting against both the upper and lower cuspids. At the same time Class III elastics were worn from the posterior of the headgear to sliding hooks acting against the lower second bicuspids to provide a distal force on the lower buccal teeth. In order to conserve anchorage these three pairs of elastics were worn only when the headgear was in place. This first phase of treatment continued for about ten months.

When the cuspids were retracted suf-

Presented before the Northwest Component of the Angle Society, 1958.

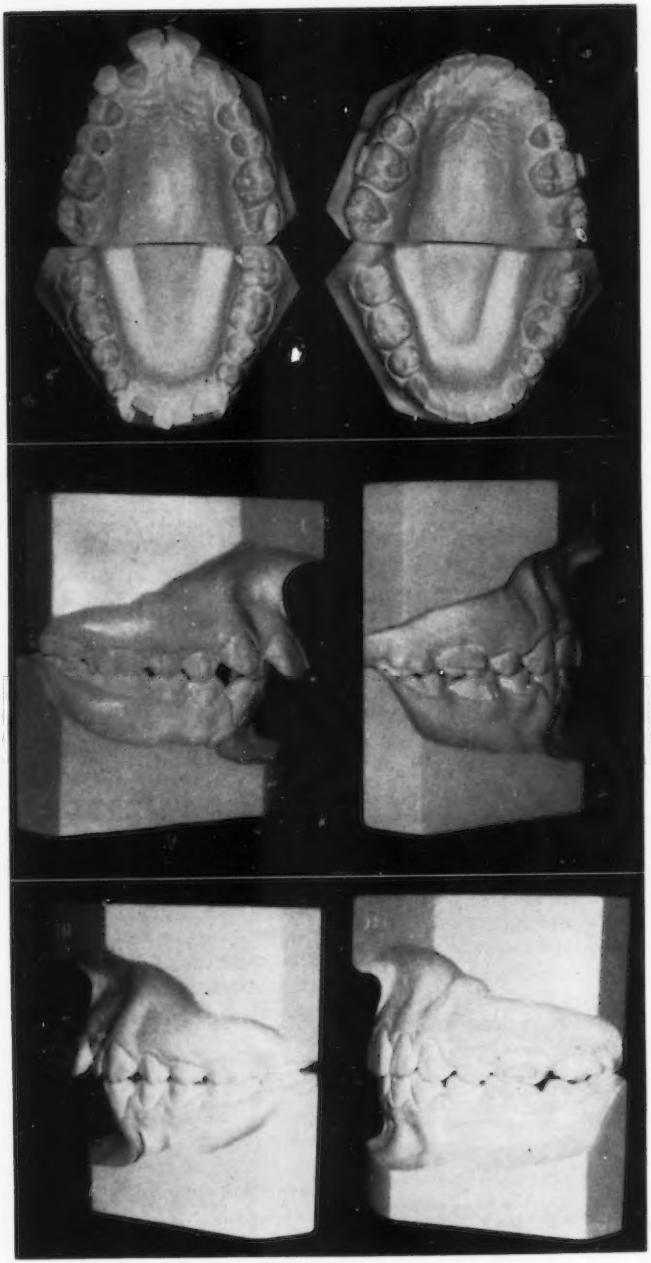

Fig. 1 Left, models before treatment. Right, during retention.

Fig. 2 Above, photographs before treatment and below, after treatment.

Table I

	9-20-56	3-25-58
Facial Plane	85	87
Convexity	5	5
A-B Plane	4	4
Mand. Plane	24	26
Y Axis	60	59
Occlusal Plane	7	10
Interincisal	110	128
$\overline{1}$ to Occlusal	25	22
$\overline{1}$ to Mand. Plane	8	9
$\underline{1}$ to AP Plane (mm)	14	5

ficiently to allow reduction of the anterior crowding, a series of round, and later, edgewise archwires with closing loops were used to close spaces. Class II elastics were worn in conjunction with the closing archwires. This second phase was completed in about eleven months.

The final phase of treatment consisted of perfecting the details of occlusion with edgewise finishing arches. This phase took eight months.

Retention

Upper and lower acrylic retainers were used to close the band space and to refine some details of occlusion. The teeth were cut from plaster models, which were made after the bands were removed, and reset in wax. This arrangement was similar to set-ups made for Kesling positioners, except that the teeth were cut off the models at the cervical enamel junction. A conventional, rigid acrylic retainer constructed on a set-up of this type might not have gone to place. Therefore, when the acrylic portion of the retainer was made, a thin layer of flexible self-curing acrylic was sprayed against some of the teeth, which might have been moved into a position of interference. Then a hard, self-curing acrylic was molded in the conventional manner to complete the acrylic portion of the retainer.

The upper and lower retainers carried cuspid clasps which crossed the arches between the cuspids and bicuspids and ended in hooks. Elastics were worn from these hooks across the anterior teeth. The ends of these hooks were placed well into the cuspid-lateral embrasure to allow the elastics to engage the lateral incisors as well as the centrals.

The action of the flexible acrylic under pressure and the action of the elastic bands against the anterior teeth produced tooth movements similar to those possible with a positioner. Retainers of this type seem to be very effective for closing band space and refining minor details of occlusion during the retention period.

Results

During treatment the crowding problem was resolved. The upper incisors were retracted from 14 mm to 5 mm when measured to the AP plane.

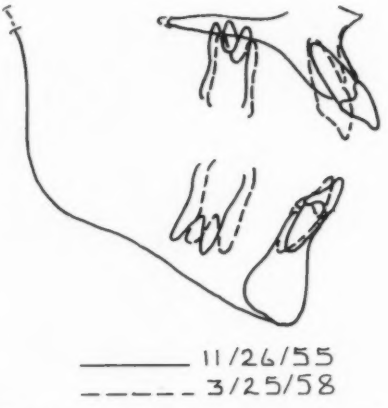

Fig. 3 Composite showing growth and changes of maxilla and mandible during treatment.

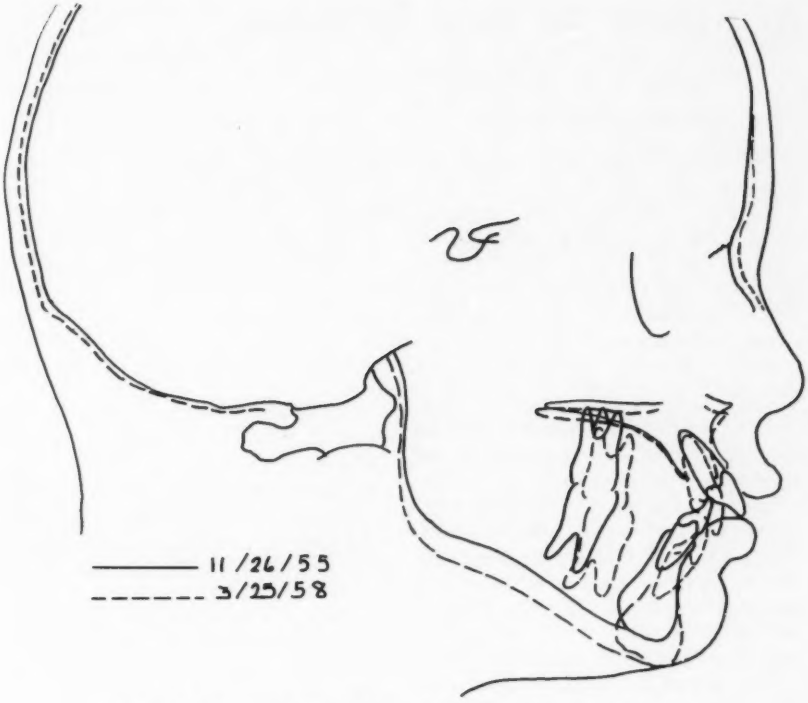

Fig. 4 Composite tracing oriented on NS and registered at S.

When tracings of the mandible before and after treatment were superimposed on the lower border and gnathion, as shown in Figure 3, it may be noted that the lower incisor was retracted about 3 mm. The composite tracing shown in Figure 4, which was superimposed on NS and registered on S, reveals that a favorable growth spurt took place during treatment.

Conclusion

My reason for presenting this particular case was to demonstrate the possible advantages of one particular method of preserving anchorage. Although the treatment time might be considered extended, the profile and occlusion seem satisfactory.

1200 High Street

Incidence Of Fractured Anterior Teeth As Related To Their Protrusion

THOMAS E. LEWIS, D.D.S.

San Jose, California

The dental profession has quite generally accepted the point of view that when anterior teeth protrude there exists an important predisposing cause of injury to those teeth. Orthodontists often recommend the reduction of protrusion of anterior teeth as a preventive measure, in addition to esthetic and other advantages to be gained.

The literature on fractured anterior teeth is devoted almost exclusively to treatment, while incidence and protrusion as predisposing factors have received little attention. Ellis[1] reported that a survey of 4251 children revealed that 4.2% had fractured teeth, with a boy-to-girl ratio of 127:51. Martin[2] compared the incidence in delinquents and non-delinquents and gave 46% for delinquents and 16% for the others, for an even boy-to-girl ratio. Glucksman[3] stated: "Coronal fracture of one or more anterior teeth is so common in certain types of malocclusion, especially Class II, Division 1, that it may be regarded as one reason for early treatment of this deformity. In 100 of this type, taken in routine order from treated cases in my collection, 11 were found to have fractured teeth". Hardwicke and Newman[4] found in a large group of children who presented for treatment that "86% of the fractures occurred in mouths with undue prominence of the affected teeth". Sweet[5] in 1942 stated that "fractures are on the increase largely due to protrusion resulting from mouth breathing", and added that "90% of the fractured anterior teeth protrude and do not have lip coverage". Zander and Law[6] also felt that protruding teeth were predisposing to fracture and claimed that injuries were increasing. Malone and Massler[7] agreed with this theme. Ellis[1] in his book cites these authors and says, "Protruding anterior teeth must be recognized as the most important predisposing factor in injury to these teeth".

The literature on the subject is not large, and it may be seen from the above that, when the figures are based on surveys, the results do not always agree and, more often than not, there have been no investigations to support the figures cited. Informal observation in the orthodontic office would seem to support these views regarding the connection between protrusion of anterior teeth and their fracture, but an objective study would be desirable, taking up the following points.

1. Is there really any discernible relationship between fractured and protruding anterior teeth?
2. Does the degree of protrusion affect the incidence or the severity of the fracture?
3. Is the incidence or the severity of fracture more severe in one sex than the other?

METHOD AND MATERIALS

A total of 343 white children, aged 8-13, were examined. All attended the same school, located in a neighborhood which was diversified with respect to socio-economic status. The children were seen in the classroom and no attempt was made to select individuals,

except for the fact that no child wearing an orthodontic appliance was included. The following were noted: age, sex, number and severity of fractured teeth, degree of protrusion (if any).

If the fracture involved only the enamel of the tooth, it was described as "mild." All other fractures were recorded as "severe". The degree of protrusion was expressed in millimeters by measuring the distance between the incisal edges of the upper incisors and the labial surfaces of the lower incisors. Measurements were made to the nearest millimeter and anything under 4 mm. was considered as non-protrusive. The classification according to Angle was not recorded, since only the protrusiveness of the maxillary incisors was considered crucial. Under this system of recording, several Class II, Division 1 malocclusions might be expected to be included as protrusive, as well as some Class I's with a similar configuration of anterior teeth. At the outset it was thought that recording coverage of the teeth by the lips would be informative, but the children were prone to assume a false lip position, making a judgment on this score unreliable. Where more than one tooth was broken, no added weight was given to this, and the case was counted only as one fracture per child.

Findings

A greater incidence of fracture was observed in the thirteen-year olds than in the eight-year olds; it seems reasonable to assume that this difference results from a longer period of exposure to accident.

The remainder of the findings are best set forth (Table I) in the tabular form customarily employed for the analysis of data by the Chi Square test, the statistical device of choice in this study.

To test whether or not chance could account for the distribution above, we must determine what we would expect from chance and chance alone. We see that in all there were 282 children (98 + 184) with no fracture. Examining the totals, we find that the entire group of 343 was distributed on the basis of 133 protrusive, 210 non-protrusive. With only chance at work, we would expect that the 282 children with no fractures should be distributed in the same 133:210 ratio of the entire group; hence our "expected" figures are 109.3 and 172.7 for protrusive and non-protrusive respectively, for a total of 282. We apply the same line of reasoning for the categories of "mild fracture" and "severe fracture". The total Chi Square value of 12.696 could occur through the operation of chance alone

TABLE I

	Children with protrusion			*Children without protrusion*		
Number with	O	E	Chi^2	O	E	Chi^2
No fracture	98	109.3	1.168	184	172.7	.739
Mild fracture	24	17.8	2.160	22	28.2	1.363
Severe fracture	11	5.9	4.408	4	9.1	2.858
Totals:	133	133.0	7.736	210	210.0	4.960

$Chi^2 = 12.696$ $p = <.01$ $>.001$

TABLE II

	Boys with protrusion			*Boys without protrusion*			
Number with	O	E	Chi^2	O	E	Chi^2	*Totals*
No fracture	47	52.2	0.518	84	78.8	0.343	131
Mild fracture	9	7.9	.184	11	12.1	0.118	20
Severe fracture ...	9	4.9	3.675	3	7.1	2.467	12
Totals:	65	65.0	4.377	98	98.0	2.928	163

$Chi^2 = 7.305$ $p = <0.05$ >0.02

less than once in a hundred times although it could occur by chance somewhat oftener than once in a thousand times. This more than satisfies the levels of probability ordinarily required, and it is therefore concluded that some factor other than chance accounts for the distribution above. In other words, there seems to be a causative relationship between the frequency and severity of fractures in anterior teeth and the presence or absence of protrusion of those teeth.

These same data may be regrouped so that boys are dealt with separately from girls. Table II sets forth the data with respect to boys only.

Table III sets forth similar data with respect to girls.

In each of these Chi Square tests carried out with boys separated from the girls, a somewhat lower Chi Square value is found, as is to be expected when the number of cases is virtually halved. Nonetheless, each of these Chi Square values is high enough that it could be expected through the operation of chance alone less than five times in one hundred, although values of this size could be expected to occur a little more often than twice in one hundred.

Summary and Conclusions

Three hundred forty-three white children were examined in a public school of San Jose, California, between the ages of eight and thirteen years. In each child the degree of protrusion of anterior teeth (if any) was noted, as well as the presence or absence of fractures in anterior teeth; if fractured anterior teeth were found, the severity was noted. Fractures were designated as mild if only the enamel of the tooth was involved, all other fractures were

TABLE III

	Girls with protrusion			*Girls without protrusion*			
Number with	O	E	Chi^2	O	E	Chi^2	*Totals*
No fracture	51	57.1	.651	100	93.9	.396	151
Mild fracture	15	9.8	2.759	11	16.2	1.669	26
Severe fracture ...	2	1.1	.736	1	1.9	.426	3
Totals:	68	68.0	4.146	112	112.0	2.491	180

$Chi^2 = 6.637$ $p = <0.05$ $>.02$

recorded as severe. Statistical analysis of the data by means of the Chi Square test suggests that there is a real relationship between the incidence of fractured anterior teeth and the protrusion of those teeth, a relationship which should not be ascribed to chance alone.

219 Meridian Road

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The Angle Orthodontist

A magazine established by the co-workers of Edward H. Angle, in his memory . . .

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Business Manager: Silas J. Kloehn.

Associate Editors: Allan G. Brodie, Morse R. Newcomb, Harold J. Noyes, Robert H. W. Strang, Wendell L. Wylie.

Vol. XXIX, No. 2 April, 1959

The Angle Orthodontist

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